Disaster Resilience Action Plan Shillong, Meghalaya

Developing Disaster Resilience Action Plan through GIS and prioritizing actions for Natural Disaster Risk Reduction in Urban Agglomerations of Shillong

Supported by:
National Mission on Himalayan Studies (NMHS), under

Ministry of Environment, Forest and Climate Change, Government of India (MoEFCC, GoI)

Prepared by:
Integrated Research and Action for Development (IRADe)

Partners:

North Eastern Space Application Centre, NESAC

GB Pant National Institute of Himalayan Environment – Sikkim Regional Centre (NIHE-SRC)

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IRADe-PR-73(2020)

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20 YEARS IRADe Integrated Research and Action for Development

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G.B. Pant National Institute of Himalayan Environment

Supported by:

NMHS
National Mission on Himalayan Studies

सत्यमेव जयते

Ministry of Environment, Forest and Climate Change
Government of India

"Developing Disaster Resilience Action Plan through GIS and Prioritizing the Actions for Natural Disaster Risk Reduction for Urban Agglomerations of Gangtok"

Supported by: National Mission on Himalayan Studies (NMHS), under Ministry of Environment, Forest and Climate Change, Government of India (MoEFCC, GoI)

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Disclaimer

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Foreword

Shillong, capital city of Meghalaya, 2nd largest city in North-East Himalayan Region of India. The city is prone to the consequences of climate change because of its geo-ecological fragility, the eastern Himalayan landscape, its trans-boundary river basins and its inherent socio-economic instabilities. Shillong city is vulnerable to both natural hazards such as landslides, heavy rainfall, floods etc. and man -made disasters such as road accidents, fires, water scarcity due to rapid growth of urbanization and improper and uncontrolled construction. With this pace of urbanisation, it can be anticipated that there are numerous challenges to keep citizens safe in case of an unforeseen disaster. It is forecasted that for East Khasi hills district (Shillong) the temperature increase is expected to be 1.6-1.7°C by 2050 (Meghalaya State Action Plan on Climate Change, 2015).

The city is highly vulnerable to the climatic environmental hazards, being a part of the mountain ecosystems, where extreme slopes lead to rapid changes in climatic zones over small distances. An appropriate, effective and efficient response is imperative for the integration of both disaster risk management and climate change adaptation. In Shillong, the slopes are steep, and being a part of young mountains, are highly vulnerable to landslides. In addition, heavy rainfall makes the land more unstable and causes massive flow of debris in every monsoon. Deforestation in the steep slopes due to human settlements and other activities results in the removal of vegetation cover and exposes rocks, resulting in the weathering processes. These processes all together trigger landslides.The entire North-eastern region is vulnerable to hazards, and technology (GIS & Remote Sensing) plays an important role to understand and mitigate such disasters. The use of Remote sensing and GIS is crucial to develop action plans which help in emergencies and disasters. The Action Plan for Gangtok focuses on ward level resilience and can be a good case study for other Himalayan cities. Collaborations between Research organizations, stakeholders, and Government is the need of the time. Such an extensive study would prove to be of great use in the planning stage for the state and Municipal Corporations to develop an Action Plan. The Sendai Framework itself enlist the target of Knowing Risk, which forms the base for planning and developing an action plan in accordance with that. Such technology (GIS and Remote Sensing) will help understanding Risks, as we know about the Disasters and its occurrence and impact; however, Risk cannot be calculated without such studies.

This report is meant to encourage discussions among policymakers, climate practitioners as well as all concerned stakeholders on Disaster management issues important to India and particularly for Himalayan cities. I congratulate the team at for their diligent efforts in putting together this report at an opportune time. I also appreciate the commitment of the authors and commend their in-depth coverage of diverse themes.

Preface

Developing Disaster Resilience Action plan through GIS and prioritizing actions for Natural Disaster Risk Reduction in Urban Agglomerations of Shillong is supported by National Mission on Himalayan Studies (NMHS), under Ministry of Environment, Forest and Climate Change Government of India (MoEFCC, GoI).

The project aims to develop Disaster Resilience Action Plans for Shillong city; with objectives to develop ward level maps at the scale of 1:4000 and to map the hazard/ disaster wise vulnerable zones of the Shillong and Gangtok urban agglomerations while identifying and mapping critical infrastructure at risk through ground surveys. This will assist in developing the Disaster Resilience Action Plan for the identified cities and prioritize actions for Disaster Risk Reduction in the Indian Himalayan Regions (IHR)
This report covers a wide range of issues, beginning with an Introduction of the scenario of Hazards in India and Himalayan region in particular. The Second chapter gives an overview of Shillong city's profile and the hazard vulnerability assessment in terms of physical and socio-economic vulnerabilities faced by the people. The third and fourth chapters gives a Hazard Risk assessment on Landslides and Urban Floods in Shillong and give a detailed profile with maps, susceptible areas and vulnerabilities. The fifth chapter focuses on the Critical Infrastructure mapping and assessment of Urban Planning in the city. In the sixth chapter the role of various stakeholders in the Disaster management is explained. Seventh Chapter describes the Early Warning Systems and Operational Preparedness. Early Warning systems, trainings and better communication is absolute essential to overcome the climate vulnerability. Chapter eight has Disaster Resilience Action Strategies which can be adapted for the short, medium and long term for disaster preparedness in Shillong.

We hope people will find the importance of this pioneer project which would set a benchmark for other Disaster Resilience Action Plans as this is the first time such High-resolution data on 1:4000 scale for Ward level is being used for the Disaster Resilience Action Plans. We are thankful to all the stakeholders for their thought-provoking comments and suggestions based on their several years of experience in this field.

Executive Summary

Climate Change is a developing issue that will only become worse unless immediate action is taken, 2016 was the hottest year ever recorded with 2020 being the second hottest year ever recorded (NASA & NOAA, 2020), Climate change has the capability of increasing the precedence of natural diesters. India is a high disaster-prone nation that is extremely susceptible to natural disasters. Up until 2011, the country had lost 140,000 lives to the 431 natural disasters that occurred (MHA (GOI), UNDP, 2011). Rising temperatures as a result of climate change will only exacerbate the effects and frequency of natural disasters. The Indian Himalayan Region (IHR) is disproportionally vulnerable to natural disasters due to its fragile geo-environmental landscape, Shillong, Meghalaya is a part of this region and is classified as a Seismic Zone V region. This paper analyses the current measures in place within Shillong to mitigate the impacts of natural disasters and provides recommendations on how to better ensure the protection of its citizens and their property.

Physical risks and vulnerabilities posed by disasters in the Himalayan cities are often accompanied by a lack of necessary resources – financial, human and institutional – as well as access to relevant scientific information to cope with them. It is virtually impossible to prevent the occurrence of natural hazards, but it is possible to contain and prevent them from turning into disasters. It is imperative to concentrate on minimizing and mitigating the magnitude of the damaging effects of disasters by undertaking plausible disaster risk reduction measures through better scientific tools and knowledge and taking steps to build the resilience of the citizens, especially vulnerable communities. Thus, there is a need for a **systematic review to collect evidence related to the impact of urbanization on disaster risk and vulnerability to natural disasters in the Indian Himalayan region.**

https://www.thenationalnews.com/lifestyle/travel/my-kind-of-place-gangtok-sikkim-india-1.156955

https://www.esikkimtourism.in/things-to-do-in-gangtok/

Report Summary

Chapter 1

This chapter provides an overview of the issue of Disasters. It begins by looking into the global climate situation and then goes onto define hazards, disasters, and vulnerability, which are essential terms in this paper. The intersection between Natural Hazard and Vulnerable Systems, Risks of Disasters, is highlighted through a Venn diagram. It then delves into a review of the frequency, occurrence, and susceptibility of the IHR to Natural Disasters. Over the last several decades, four major earthquakes have occurred in the region, this is in addition to other natural disasters such as landslides, cyclonic storms, and urban floods. The underdevelopment of the region renders it even more vulnerable to natural disasters, there is a lack of financial, human, and institutional resources that can effectively mitigate the risks of such hazards.

Chapter 2

The chapter delves into the area of study, Shillong city, Meghalaya. The hilly state exists in the northeastern region of India and is bordered by Assam in the north and Bangladesh in the south. It consists of 26,64,007 peoples, 11 districts, 39 blocks, and 6839 villages. Shillong is prone to natural disasters such as cyclonic storms, floods, landslides, and earthquakes. Some of the effects of such disasters are amplified during the monsoon season. Along with this, there have been other aggravating factors such as the increasing levels of urbanization with the region, the city has experienced unprecedented population growth with an increase of 7.79% over the last decade (Census, 2011). As a result of this, the city is vulnerable to man-made disasters such as fires and scarcity. This chapter also conducts a rapid vulnerability assessment which outlines what external factors have been and will continue to be a potential threat to the city. Finally, it examines which socioeconomic groups and districts are disproportionately vulnerable.

Chapter 3

This chapter on "Hazard Risk Assessment - Landslides" otlines definition of landslide, "movement along the slope of the mass, earth, or debris, occurring when the slope changes from a steady to an unsteady state. It further segments the different types of landslides capable of occurring into 5 types; Fall, Topple, Slide, Spread, Flow, and Subsidence. Graphs depict the circumstances under which each type occurs. In Meghalaya, landslides caused approximately 22 deaths in 2014 (Revenue and Disaster Management, Govt of Meghalaya). Landslides are relatively less frequent in Shillong as compared to their frequency in other Meghalayan regions, however, since Shillong is extremely prone to severe earthquakes the threat of landslides instigated by earthquakes can never be ruled out. The chapter also heavily employs maps to provide an image of the most susceptible regions based on different factors.

Chapter 4

This chapter provides a hazard risk assessment for urban floods. Urban floods are a "result of inadequate or poor maintenance of stormwater drains, improper planning, encroachment on drains and water bodies, occupation of low-lying areas, modification of catchments, and Climate Change". Flash floods differ from this as they occur within 6 hours of heavy rainfall or any such causative event. Urban floods can be classified into local heavy rainfall, river overbook flow, and storm surges. Due to inadequate structural facilities flash floods occur during the monsoon season in Shillong. Furthermore, GIS mapping capabilities are utilized to present maps the display the most vulnerable zones to different facets such as slopes, elevations, drainage density, etc.

Chapter 5

The chapter comprises a hazard risk assessment for earthquakes. An earthquake is a phenomenon of sudden shaking of the earth's crust due to natural causes (rock displacements, landslides, meteoritic impact, etc). As India is located atop two continental plates, the region is extremely prone to earthquakes. Shillong, in 2016, experienced a 6.4 magnitude earthquake that caused minor structural damage throughout the city. Its disaster-prone nature is partly due to the fact the city is located on the Shillong Plateau (SP) which is one of the most seismically active regions in the world. This chapter also presents various vulnerability maps based on different causing factors.

Chapter 6

This chapter analyzes the Critical Infrastructure, Mapping and Assessment, and Urban Planning. Critical infrastructure is necessary as with appropriate structures the effects of natural calamities can be drastically mitigated. Shillong lacks a sufficient water supply, 50% of the population relies on vendor tankers and private wells, or small springs. These issues are amplified as the portion of the population that relies on the river Umium has to deal with an antiquated water supply system which further hinders the state's ability to distribute water. Shillong lacks the approbate processes to discard solid waste which deteriorates the level of cleanliness in the city, neither do they have complete stormwater drainage connectivity. Additionally, traffic on most minor and major roads is disrupted relatively frequently as a result of flooding. Furthermore, the Urban Risk Reduction Programme has been implemented in Shillong city, this plan has an emphasis on community awareness and capabilities as the community is usually the first responder so the population must be equipped in case of any such disaster. The 'District Disaster Management Plan, East Khasi Hills District, Shillong, 2015' includes instigating institutional change through collaboration with the District Crisis Management group

Chapter 7

This chapter discusses Urban Basic Infrastructure and Disaster Resilience. Such infrastructure is essential as these are the services that people rely on the most while also being one of the first services to lose its ability to provide due to a disaster. Service Level Benchmarks for outlined for Shillong. For the indicator water supply, Shillong is either primarily below or does not have information for the determinants. For the indicator Sewage Management, Shillong is severely below the standard for most determinants. For Solid Waste Management, once again, Shillong is severely below almost all determinants. To improve its water supply, the chapter recommends encouraging rainwater harvesting practice in all residential, govt, and commercial buildings. For Sewerage management, the installation of sewerage treatment plants for treatment and recycling of wastewater is recommended. For Solid Waste Management, the chapter recommends the installation of public bins in the appropriate areas. For stormwater drainage, upgrading the existing drains is recommended. For transportation, the chapter recommends planning and provision for walking tracks, footpaths, and streetlights along the major roads. For electricity, the installation of the underground wiring and removal of transformers to avoid traffic hindrance is recommended. In terms of housing, the chapter recommends the provision of basic infrastructure and services to the urban poor.

Chapter 8

The chapter looks into Disaster Management and Stakeholder Role in Disaster Management. This chapter outlines what is meant by before, during, and after disaster activities and how each is beneficial in limiting the damage incurred as a result of a natural calamity. The chapter also outlines which stakeholder is responsible for what action. The local residents of Shillong are the Primary stakeholders while most government agencies are key stakeholders. The relationships between the stakeholders are also highlighted.

Chapter 9

This chapter assesses the Early Warning Systems and Operational Preparedness. Shillong does not currently have any monitoring or warning system for Landslides, since in the region landslides have been generally linked with earthquakes and heavy rainfall therefore, they serve as a natural warning system. But the Meghalaya State Disaster Management Authority has updated and amended its construction bylaws, among other things, to mitigate risks. In regard to floods, the current Flood Early Warning Systems (FLEWS) has accurately predicted 85% of major earthquakes in the state of Assam and other states in the region and has been implemented the river Umiam. Being prepared for such calamities involves collaborative efforts between the Shillong governmental agencies and the Indian Meteorological Department, Meghalaya Disaster Management Authority, Revenue, and Disaster Management, East Khasi Hill District Disaster Management Authority likewise.

Chapter 10

This chapter evaluates Traditional Knowledge in Building Disaster Resilience. In Meghalaya, many of the local tribes believe in "U Basa", a goddess that lives in thick virgin forests, this belief aids in protecting the environment as the tribes protect the forests from any sort of deforestation. Houses in Shillong are constructed with stilts on top of stable grounds so that can resists earthquakes and these houses follow the concept of Bioclimatic Architecture. A common type of house in Shillong is a Khasi House, these house types are oval in shape which helps minimize stress concentrations during earthquakes. Moreover, in order to prevent landslides bamboo embankments and wood logs are used to control soil erosion and thereby landslides. Passing down, and around, such knowledge is an essential step in capacity building for the entire population and aligns with the goals of the Urban Risk Reduction Programme.

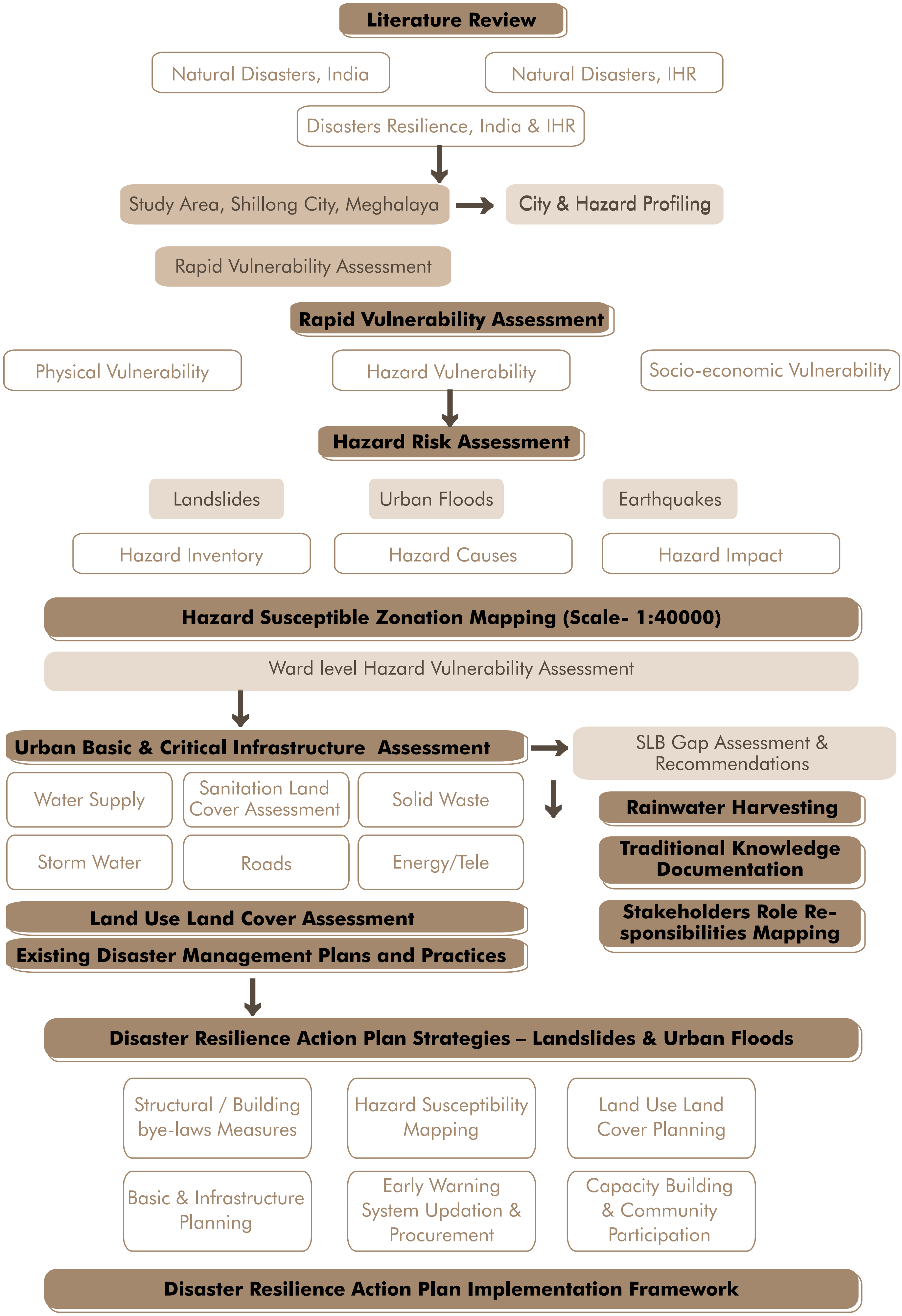
Chapter 11

The chapter discusses Disaster Resilience Action Strategies. For Landslide prevention, in terms of construction, in the short run, the enforcement of regulations on indiscriminate quarrying and mining operations along the slopes is recommended, in the medium-term it is recommended that unstable slopes be demarcated and re-excavated to bench them with geonets or bionets or jute matting to promote vegetation growth, and In the long run, Identifying and assessing Nature-Based Solution (NBS) for landslide Risk Management Invalid source specified is recommended. Such measures are recommended for Landslide susceptible donation, Land-Use and Land cover Planning, basic critical infrastructure, Community Capacity Building, and Landslide Early Warning System.

Chapter 12

This chapter outlines Resilience Action Plan Implementation Framework and the conclusion. The Shillong City Disaster Management Plan, 2018 provides insight into an emergency response plan, a system that will allow for a quick response to such disasters. The 2016 Meghalaya Disaster Management Plan provides a participatory, well-structured, fail-safe, multi-disciplinary, multi-departmental, and systematic approach to guide administrative mechanisms at all levels of the Government. It has a strategic plan to tackle the impacts of earthquakes, floods, and landslides. Conclusively, due to increasing levels of urbanization and unregulated construction work the natural drainage system is blocked, thereby making Shillong more susceptible to floods. The study of the existing Plans and the review of the actions initiated by Meghalaya Disaster Management Authority and East District Disaster Management Authority indicate that there is a need of strengthening the early warning system for floods and thunderstorms in the city. The plan emphasizes the short -medium-long term Structural and Non-structural resilience action strategies/measures to mitigate and adapt to the existing physical and socio-economic vulnerability.

Disaster Resilience Action Structure



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Abbreviations

A
AHP
Analytical Hierarchy Process
AC
Atmospheric Correction
AMRUT
Atal Mission for Rejuvenation and Urban Transformation
B
BEL
Bharat Electronics Limited
BIS
Bureau of Indian Standard (BIS)
C
CLRSM
Centre for Landslide Research Studies and Management (CLRSM)
CDMC
City Disaster Management Committee (CDMC)
CDMP
City Disaster Management Plan (CDMP)
CDRI
Coalition for Disaster Resilient Infrastructure (CDRI)
CMP
Comprehensive Mobility Plan (CMP)
D
DBMS
Database Management System (DBMS)
DCR
development control regulations (DCR)
DRR
Disaster Risk Reduction (DRR)
DCMG
District Crisis Management Group (DCMG)
DDMA
District Disaster Management Authority (DDMA)
DEOC
District Emergency Operation Centre (DEOC)
E
EWS
Early Warning Systems (EWS)
EOCs
Emergency Operation Centres (EOCs)
ESF
Emergency Support Function (ESF)
F
FLEWS
Flood Early Warning Systems (FLEWS)

G

GMC

Gangtok Municipal Corporations (GMC)

GIS

geographic information system (GIS)

GSI

Geological Survey of India (GSI)-Gangtok

GFLD

Global Fatal Landslide Database (GFLD)

GSHAP

Global Seismic Hazard Assessment Program (GSHAP)

H

HHs

households (HHs)

HRVA

(Hazard Risk Vulnerability Assessment)

I

IAP

Incident Action Plan (IAP)

IC

Incident Commander (IC)

IRS

Incident Response System (IRS)

IRTs

Incident Response Teams (IRTs)

IHR

Indian Himalayan Region (IHR)

IIPA

Indian Institute of Public Administration (IIPA)

IITG

Indian Institute of Technology, Guwahati (IITG)

IMO

Information & Media Officer (IMO),

IPDS

Integrated Power Development Schemes (IPDS)

ISTRAC

ISRO Telemetry Tracking and Command Network (ISTRAC)

L

LU/LC

Land use/Land cover (LU/LC)

LEWS

landslide early-warning system (LEWS)

LO

Liaison Officer (LO).

M

ML

Maximum likelihood (ML)

MATI

Meghalaya Administrative Tanning Institute (MATI), MWF

Meghalaya Water Foundation (MWF)

MMI

Modified Mercalli Intensity (MMI)

MSDMA

Meghalaya State Disaster Management Authority (SSDMA)

N

NDMA

National Disaster Management Authority (NDMA)

NSLM

National Landslide Susceptibility Mapping (NLSM) programme

NBS

Nature-Based Solution (NBS)

NEEPCO

NEEPCO (North Eastern Electric Power Corporation Limited)

NMT

(Non-Motorised Transportation)

NE

NorthEast (NE)

P

PDWR

Polarimetric Doppler Weather Radar (DWR)

R

RVS

Rapid visual survey (RVS)

REA

Reliability ensemble average (REA)

ROs

Responsible Officers (ROs)

S

SO

Safety Officer (SO)

SLB

Service Level Benchmarks (SLB)

SMB

Shillong Municipal Board (SMB)

SP

Shillong Plateau (SP)

SWM

Solid Waste Management (SWM)

SOPs

Standard Operating Procedure (SOP)

SAPCC

State Action Plan on Climate Change (SAPCC)

U

UNDP

United Nations Development Programme (UNDP)

ULB

Urban Local Body (ULB)

URR

Urban Risk Reduction(URR)

Chapter 1

Introduction

1.1 Climate Disaster World Scenario

The number and scale of disasters triggered by natural hazards are increasing (UNISDR, 2016). There is wide evidence on the impact of Climate change, increasing the frequency and magnitude of climate hazards. 2016 was the hottest year ever recorded, and 2019 was the second-hottest year ever recorded in history (NASA & NOAA, 2020). The number of disasters continues to rise due to a combination of increasing vulnerability, unsafe new settlements and dangerous climate changes. Climate change affects disaster risks in two ways - increase in weather and climatic hazards, and through increases in the vulnerability of communities to natural hazards, particularly through ecosystem degradation, reductions in water and food availability, and livelihood changes. Climate change adds yet another layer of stress to environmental degradation and rapid unplanned urban growth, further reducing communities' abilities to cope with even the existing levels of weather hazards (UNISDR , WHO, 2008).

1.2 Natural hazards and Disasters

1.2.1 Terminology

Hazards

A condition/event that has the potential for causing injury/ loss of life or damage to property/ environment.

Hazards are termed as disasters when they cause widespread destruction of property and human lives. Once a hazard becomes active and is no longer just a threat, it becomes a disaster
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Disaster

A catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or manmade causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area. "community or society to cope using its own resources."
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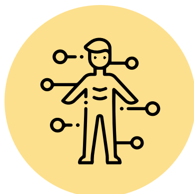

Vulnerability

The inability to resist a hazard or to respond when a disaster has occurred. For instance, people who live on plains are more vulnerable to floods than people who live higher up. In actual fact, vulnerability depends on several factors, such as people's age and state of health, local environmental and sanitary conditions, as well as on the quality and state of local buildings and their location with respect to any hazards.
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1.2.2 Risk of Disasters

Disaster risk is widely recognized as the consequence of the interaction between a hazard and the characteristics that make people and places vulnerable and exposed.

Disasters are sometimes considered external shocks, but disaster risk results from the complex interaction between development processes that generate exposure, vulnerability, and hazard conditions. Therefore, disaster risk is considered the combination of the severity and frequency of a hazard, the number of people and assets exposed to the hazard, and their vulnerability to damage. Intensive risk is disaster risk associated with low-probability, high-impact events, whereas extensive risk is associated with high-probability, low-impact events. (UNDRR, 2015).

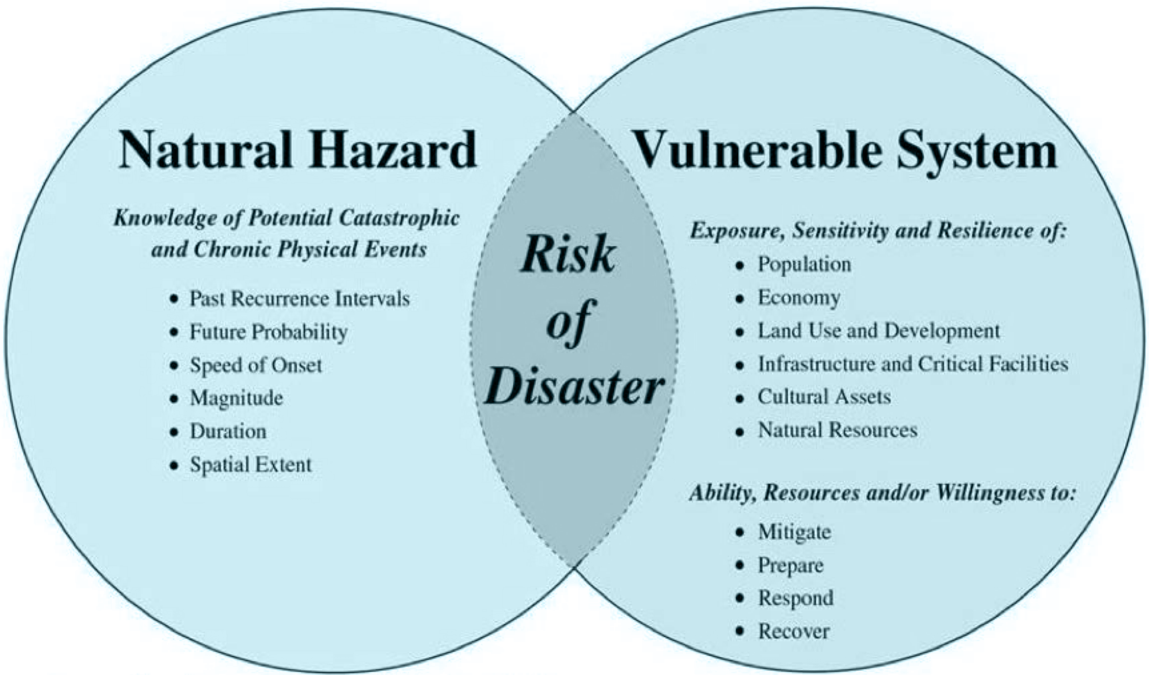

Figure 1 Understanding the risk Invalid source specified.
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Disaster risk is expressed as the likelihood of loss of life, injury or destruction and damage from a disaster in a given period of time (UNDRR Global Assessment Report (2015).

The definition of disaster risk reflects the concept of hazardous events and disasters as the outcome of continuously present conditions of risk.

CITATION UND17 \l 1033 (UNDRR, Terminology, 2017)

1.2.3 Frequencies of Disasters, Population Vulnerability and Economic Losses

Natural Disasters

2020
416 Natural Disasters recorded (Statista)

2019
recorded 361 – 409 natural disasters across the globe (AON, 2019)

2018
315 natural disaster events recorded (CREED, 2018), worldwide

2008-2017
annual average numbers disaster events accounted to 348 across the globe

Population Vulnerability

2019
More than 10,000 people lost their lives to natural disasters (EMDAT, 2019)

2018
Disaster events recorded with 11,804 deaths. Over 0.068 billion people were affected (CREED, 2018)

2008-2017
annual average of 67,572, deaths, annual average of 0.198 billion people affected (CREED, 2018)

Economic Loss

2020
SD 268 billion (AON, 2020)

2019
USD232 billion (AON, 2019)

2018
USD131.7 billion (AON, 2019)

2008-2017
SD166.7 billion (annual average) (AON, 2019)

Figure 2: Natural Disasters and Losses, 2008-2019

Low frequency but high impact events like cyclones and earthquakes cause very high economic damage and deaths compared to frequent disasters like heat waves, landslides and floods. A 2019 article in the Indian Growth and Development Review confirms empirically that damages due to floods adversely affects the per capita GSDP (Gross State Domestic Product) growth across States (Yashobanta Parida, Prarthna Agarwal Goel, 2020).

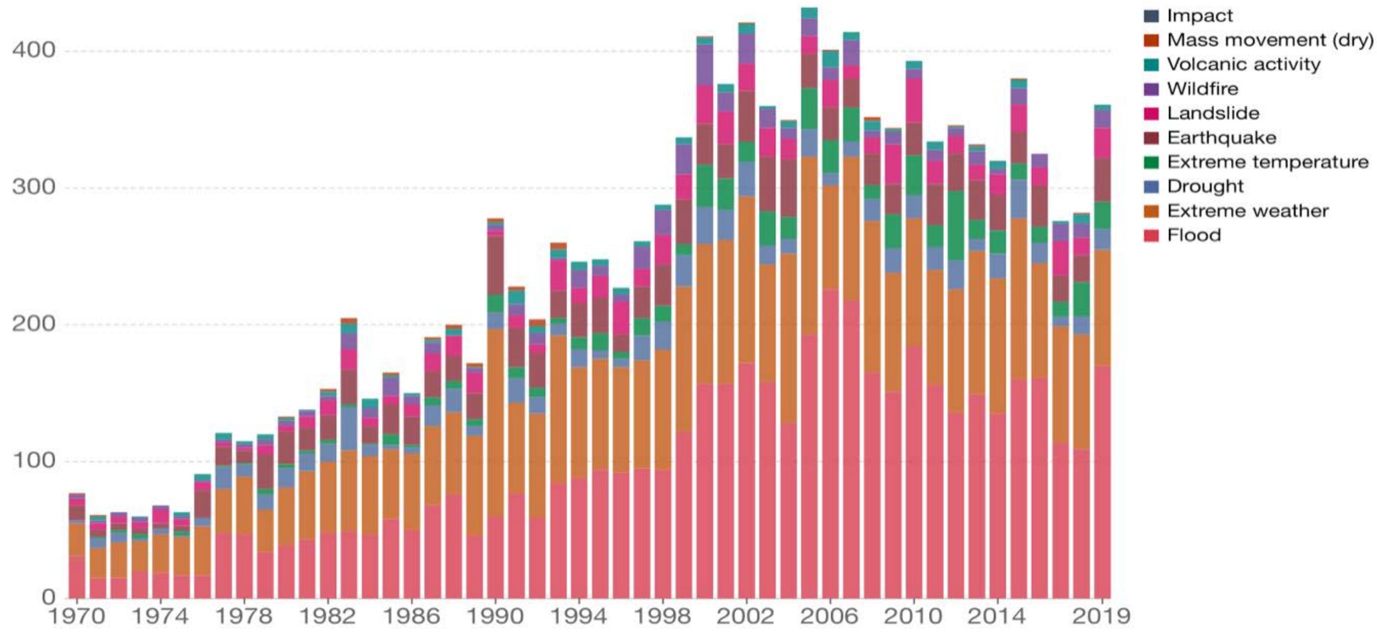


Figure 3:Global Natural Disasters, 1970-2019 (EMDAT, 2019)

The annual reported number of natural disasters, categorized by type, has increased over the years, including weather and non-weather-related disasters. The above fig. 3 depicts the number of global reported natural disaster events in any given year (1970-2019). This includes drought, floods, extreme weather, extreme temperature, landslides, dry mass movements, wildfires, volcanic activity and earthquakes. Historically, droughts and floods were the most fatal disaster events. Deaths from these events are now very low – the most deadly events today tend to be earthquakes.

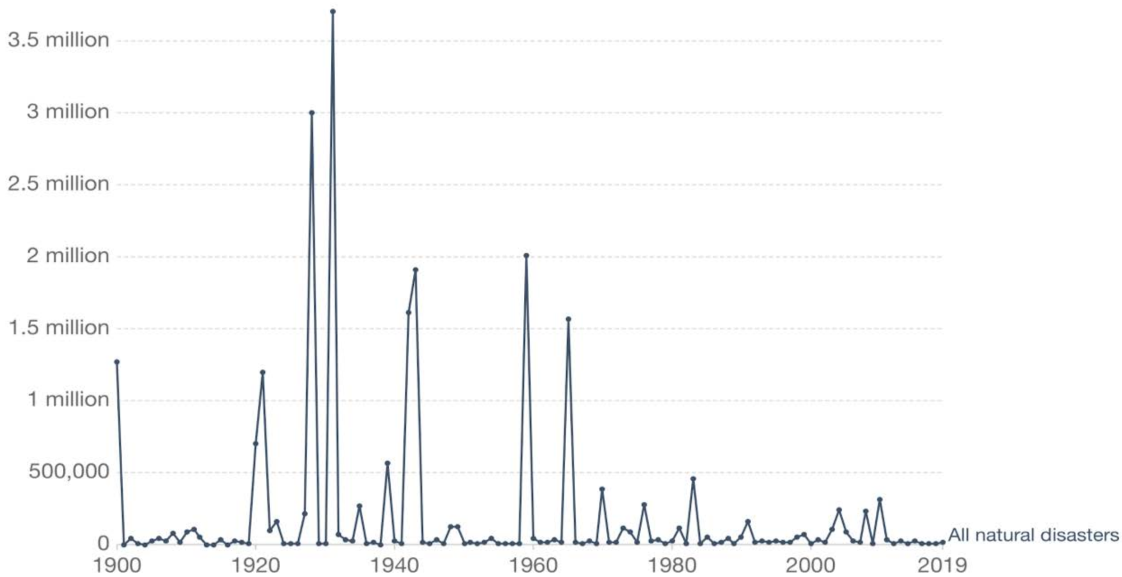


Figure 4: Death related to Natural Disasters, 1900-2019 (EMDAT, 2019)

Over the past decades, on average, approximately 60,000 people globally died from natural disasters each year, with earthquakes, floods and droughts resulting in many deaths. Over the last few decades, most years with a high death toll tend to result from large earthquake events. (EMDAT, 2019). The above Fig. 4 indicates the absolute number of global deaths per year due to natural disasters. "All-natural disasters" include drought, floods, extreme weather, extreme temperature, landslides, dry mass movements, wildfires, volcanic activity and earthquakes. The year 1931 recorded the highest number of deaths (3.71 million) due to natural disasters; however, the numbers have declined over the past century.

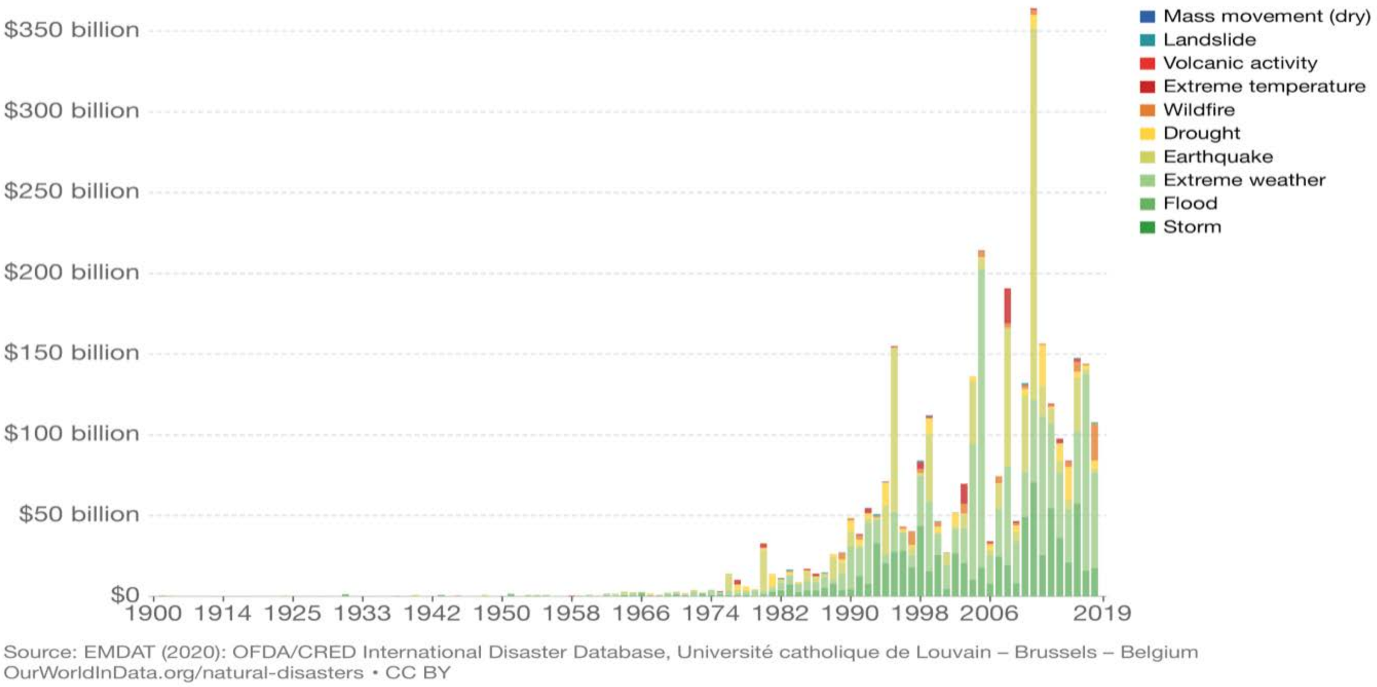


Figure 5: Economic loss due to Natural Disasters, 1900-2019 (EMDAT, 2019)

Natural disasters not only have devastating impacts in terms of the loss of human life but can also cause severe destruction with economic costs. the above figure. 5, indicates the economic cost incurred due to ant natural disasters ranging between 50 billion USD to 250 billion USD. Over the decades the economic loss has increasing due to extreme events, floods, and earthquakes.

1.3 Hazard Vulnerability of India

India is geographically located in a high disaster-prone region and has been continuously impacted by natural disasters, including floods, cyclones, landslides, earthquakes, heatwaves and Tsunami. 27 out of 35 states and union territories are prone to these types of hazards (NIDM, 2014). During 1980-2010, India has experienced nearly 431 natural disasters killing around 0.00014 billion people and affecting around 150 million people, with an estimated economic loss of USD 48.06 billion (MHA (GOI) , UNDP, 2011). Over the past thirty years, earthquakes have accounted for 34.8% of total deaths by natural disasters (NIDM, 2014). With growing urbanization and increasing occurrences of small and large-scale disasters in urban areas, years of development effort and infrastructure are continually destroyed and eroded (Sanderson, D, 2000). The recent floods in Chennai (2015) and Srinagar in 2014 show that a decade of progress and poverty alleviation can be wiped out in days.

The geo-climatic conditions and high socio-economic vulnerability make India one of the most disaster-prone countries in the world. Between 1996 and 2001, India lost 2% of its national GDP to natural disasters, and nearly 12% of government revenue was spent on relief, rehabilitation and reconstruction (MHA (GOI) , UNDP, 2011). Over the past thirty years, earthquakes have accounted for 34.8% of total deaths by natural disasters.

Global Climate Risk Index report 2019 stated that India was the 14th most vulnerable country in 2017 due to extreme weather-related events, with lost registered around 2,736 lives in 2017 due to disasters.

However, the **Global Climate Risk Index report 2020** (David Eckstein et al, 2020), ranks India **5th in 2018** on the global vulnerability ladder, with the highest recorded number of fatalities due to climate change and the second-highest monetary losses from its impact in 2018. India's high rank is due to severe rainfalls, followed by heavy flooding and landslide that killed more than 1000 people. The Monsoonal Flooding in **2018** caused 1424 deaths with an economic loss of USD 1.5 billion in India (AON, 2019). Furthermore, in 2019 India faced a wide range of natural disasters, from unbearable heatwaves to record several cyclones, record-breaking amounts of rainfall, and other extreme events occurring across the country. The decade accounted for the five warmest years on record, with 2016 the hottest (SEEDS, 2019).

According to Weather, Climate Catastrophe Insight for 2019 (AON, 2019), in **2019**, there were a total of 409 natural disaster events in 2019, at a global scale, with 41 recorded in India. The monsoon floods in India was the deadliest among them, causing 1,750 deaths. This was followed by Cyclone Fani that affected Andhra Pradesh and Odisha, apart from Bangladesh. About 72 people reportedly died in the severe cyclonic storm. The economic loss to the country due to the destructive monsoon last year was estimated at USD 10 billion.

In contrast, Cyclone Fani resulted in a cumulative loss of USD 8.1 billion to India and Bangladesh (AON, 2019). Extreme weather claimed more than 1,500 lives in 2019, the seventh-hottest(IMD, 2019) (Agence France Press, 2020), including 850 people killed by heavy rain and flooding and another 350 in summer temperatures and lighting and storms claimed another 380 lives. India recorded eight cyclones that formed over the north Indian Ocean, just below the record of 10 cyclones in 1976 (IMD, 2019).

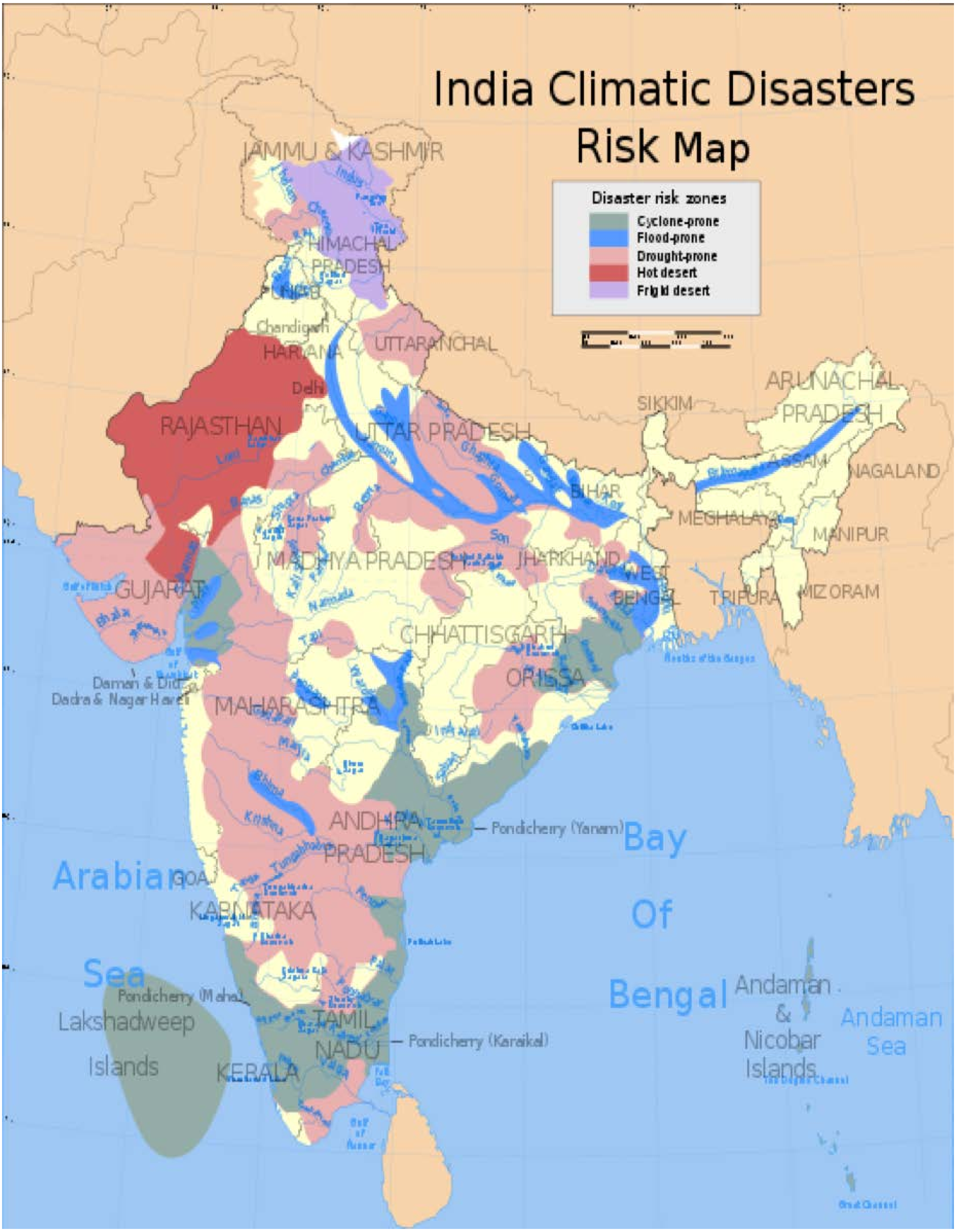


Figure 6: Climate Disaster Risk Map of India | Source: Vulnerability Atlas of India, Third Edition 2019, BMTPC, MHUA, GoI & NIDM

India has experienced exponential urban growth in the last few decades. The urban population of India has grown from 0.28 billion in 2001 to 0.37 billion in 2011, and it is further expected to grow by 25%, with reference to 2011, to 1.52 billion by 2036 (National Commission on Population, 2020). The pattern of urbanization in India is characterized by the continuous concentration of population and activities in large cities.

This is manifested in a high percentage of the urban population being concentrated in Class 1 cities (cities with more than 100,000 populations). According to the 2011 Census, there are 468 Class 1 cities, whereas, in 2001, there were 399 such cities. 70% of the urban population in India now resides in Class 1 cities. Urbanization exerts environmental stress (air, water and land pollution, deforestation), which increases the frequency of natural disasters like floods, landslides, water scarcity and others. Besides, poor legal enforcement of regulations and inadequate infrastructure services increase the vulnerability of the socially and economically marginalized people in cities, including women & children.

Cities have complex and inter-connected socio-technical systems where food, fuel and water supplies, drainage, mobility, communications and health care services rely increasingly upon uninterrupted energy provision and all-weather transport infrastructures such as roads, bridges and railway networks. Disruption of any of these would have repercussions on the functioning of the city and the well-being of its residents. Due to the concentration of people and property, a hazard can turn into disasters that affect millions of people and property with aggregate worth billions. Disasters and climate change impacts are making cities more susceptible to environmental risks. Some natural hazards turn into disasters due to unsustainable development practices, inadequate compliance of codes, lack of capacity to handle crisis events and lack of will to enforce measures that restrict urban growth in vulnerable areas.

1.4 Disaster overview in Indian Himalayan Region (IHR)

The Indian Himalayan region covers 16% of India's total geographical area, spread over 12 states (ENVIS, 2018). The Union Ministry of Environment and Forests, 2010, identified the Himalayan region as one of the four most vulnerable areas to disaster. Almost two-thirds of this region is designated forests, but "with few exceptions, most of this forest has been cut." The Indian Himalayan Region (IHR) is considered vulnerable to natural disasters like earthquakes, floods, landslides and forest fires. (GBPIHED, 2016)

According to the United Nations-affiliated organization and Planning Commission, the Himalayan region, on average, is hit by 76 disasters, killing 36,000 people and affecting 178 million people every year (United Nations-affiliated organisation, 2013). Nepal-based International Centre for Integrated Mountain Development claimed that India's Himalayan region was hit by 532 natural disasters between 1990-2012 (ICIMOD, 2012).

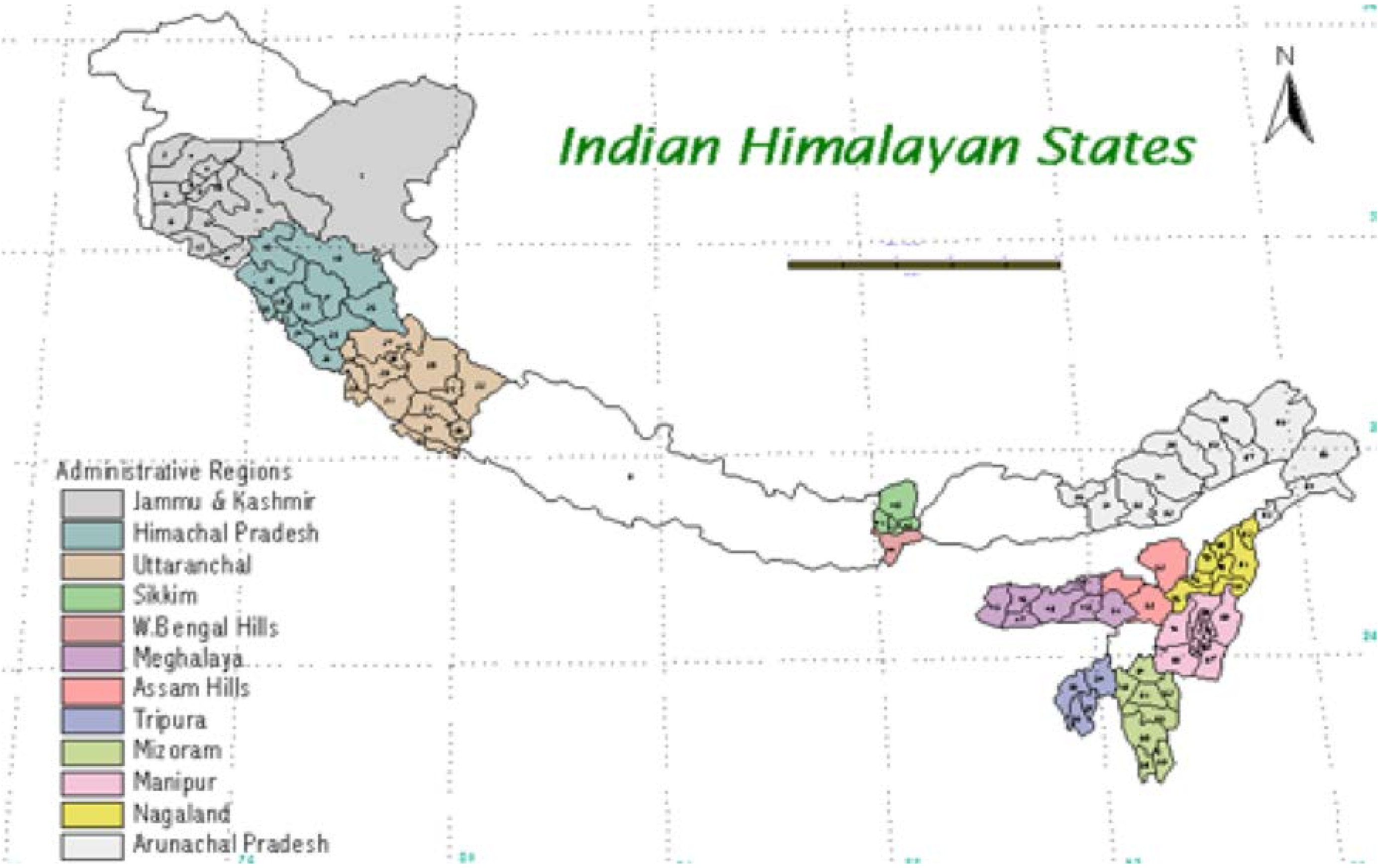


Figure 7: Indian Himalayan States (GBPIHED, 2016)

Source: http://gbpihedenvis.nic.in/indian_him_reg.htm

Disasters like high-intensity earthquakes of a magnitude exceeding 8.0 on the Richter Scale have shaken the region in the past. Scientists warn that such severe earthquakes are likely to occur anytime in the IHR, which would adversely affect the lives of several million people in India.

Heavy rainfall, seismic activity or unexpectedly rapid snowmelt, followed by a chain of consequences, triggers the hazard process in the hilly regions. These result in a chain of impacts, directly affecting the vulnerable section. One of the major hazards is glacial lake outburst floods, which are likely to increase due to permafrost thaw and glacial retreat, exposing mountain slopes and destabilizing the environment. This will increase the potential of landslides, avalanches and debris flow hazards, which can hit the glacial lake and trigger an outburst flood. (Nussbaumer, S., Schaub, Y., Huggel, C., and Nat, A. W, 2014).

Northeast (NE) India is vulnerable to natural and man-made disasters like landslides, torrential rainfall, flash floods, earthquakes, and forest fires because of its location in the eastern Himalayan periphery, fragile geo-environmental setting and economic underdevelopment. In the last several decades, four major earthquakes have occurred in the Himalayan region: Shillong, 1897 (M8.7); Kangra, 1905 (M.8.0); Bihar–Nepal, 1934 (M 8.3); and Assam–Tibet, 1950 (M 8.6) (Rajendran et al, 2015).

A high degree of vulnerability to these disasters will increasingly make the region environmentally insecure in the future unless pragmatic interventions are made immediately. The seven states of the NE region lie in Seismic Zone V, and Sikkim lies in Zone IV, which poses serious threats to life and property.

Major Disasters in the Himalayan region is listed below:

Year	Region	Disaster Type	Deaths	Economic loss
1905, April	Kangra, Himachal Pradesh	Earthquake	20,000	
1991, October	Uttarkashi, Uttarakhand	Earthquake	768-200	USD0.06 billion
1998, August	Malpa, Uttarakhand	Landslide	221	
1999, March	Chamoli, Uttarakhand	Earthquake	103	
2005, October	Kashmir	Earthquake	86000 deaths (Pakistan provinces and adjacent areas of India & Afghanistan)	
2015, April	Nepal	Earthquake	9000 killed, 22000 injured	
2012, Jun-Sept	Assam	Flood triggered 27 Landslides	149	583 hectares of cropland
2012, August	Uttarkashi	South West Monsoon- Flash floods and Landslides	34	
2012, August	Himachal Pradesh	South West Monsoon- Flash Flood	29	USD 0.13 billion
2012, September	Okhimath, Uttarakhand	Landslide	69	
2013, June	Uttarakhand, Himachal Pradesh	Cloudburst- Flash floods & Landslides	5748	4,550 villages were affected
2014, September	Jammu & Kashmir	Flood	300 people died, and 25 persons injured	USD 1.32 billion and 0.0003 billion households were damaged
2015, April	Nepal	Earthquake	9000 killed, 22000 injured	
2016, January	Manipur	Earthquake	Seven killed, over 90 injured	

Table 1: Major Disasters in the Himalayan region | Source: (CRED) EM-DAT, Belgium, USGS, National Geophysical Data Center / World Data Service (NGDC/WDS), Wadia Institute of Himalayan Geology, Disaster Management of India, Ministry of Home Affairs, GoI

1.5 Disaster Resilience in the Himalayan region

Northeast India is vulnerable to natural and man-made disasters because of its location in the eastern Himalayan periphery, fragile geo-environmental setting and economic underdevelopment. A high degree of vulnerability to these disasters will increasingly make the region environmentally insecure in the future unless pragmatic interventions are made immediately. The vulnerability of the entire N.E. region with reference to earthquake, floods and high wind velocities is very high. The seven states of the N.E. region lie in Seismic Zone V, and Sikkim lies in Zone IV, which poses serious threats to life and property. Every year Assam and some parts of Arunachal Pradesh are facing tremendous socio-economic losses due to floods. For example, There are a total of 449 embankments in Assam, covering an area of about 4,459 km of stretch. While the state water resource department had already identified 950 km of embankments as extremely vulnerable, about 2,390 km stretch of the total length of embankments has been identified as vulnerable (Das, 2012). On January 4, 2016, an earthquake of magnitude 6.7 rocked the whole of North-Eastern India and claimed seven lives and over 90 injured in Manipur (The Hindu, 2016), which is even otherwise highly prone to various kinds of natural calamities, including floods, river-bank erosion, landslides and forest fires.

Physical risks and vulnerabilities posed by disasters in the Himalayan cities are often accompanied by a lack of necessary resources – financial, human and institutional – as well as insufficient access to relevant scientific information to cope with them. Such constraints call for an urgent need to enhance the knowledge base and adaptive capacity of cities by the integration of disaster risk reduction into urban planning. Losses caused due to floods in Srinagar city of Jammu & Kashmir (2014) were estimated to be USD 1.32 billion, and 0.0003 billion households were damaged (Sphere India, 2014). This is evident that disasters can wipe away years of economic development and make people further socially and economically marginalized. Climate change affects disaster risks in two ways - increase in weather and climatic hazards, and through increases in the vulnerability of communities to natural hazards, particularly through ecosystem degradation, reductions in water and food availability, and livelihood changes. Climate change adds yet another layer of stress to those of environmental degradation and rapid unplanned urban growth, further reducing communities' abilities to cope with even the existing levels of weather hazards (UNISDR , WHO, 2008).

It is virtually impossible to prevent the occurrence of natural hazards, but it is possible to contain them and prevent them from turning into disasters. It is imperative to concentrate on minimizing or mitigating the magnitude of their damaging effects by undertaking plausible disaster risk reduction measures through better scientific tool and knowledge and taking steps to build the resilience of the citizens, especially vulnerable communities. Thus, there is a need for a systematic review to collect evidence relating to the impact of urbanization on disaster risk and vulnerability to natural disasters in the Indian Himalayan region.

1.6 Integration with Sendai Framework

The Third World Conference on Disaster Risk Reduction (March 18, 2015) reviewed the implementation of the Hyogo Framework for Action towards adopting a new framework to reduce disaster risk across the world and formulated the next generation of international strategies for disaster risk reduction. **The Sendai Framework for Disaster Risk Reduction 2015-2030 outlines seven clear targets and four priorities for action to prevent new and reduce existing disaster risks:**

- Understanding disaster risk;
- Strengthening disaster risk governance to manage disaster risk;
- Investing in disaster reduction for resilience and;
- Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction.

It aims to achieve the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries over the next 15 years. The implementation of the Sendai Framework involves adopting integrated and inclusive institutional measures so as to work towards preventing vulnerability to disaster, increase preparedness for response and recovery and strengthen resilience.

Following this,in **June 2016**, the Prime Minister of India released the country's first-ever **National Disaster Management Plan**, a document based on the global blueprint for reducing disaster losses. The document aims to make India disaster resilient and significantly reduce the loss of lives and assets. India is the first country in the world to integrate the 'Sendai Framework' in its National Plan to tackle disasters. Publication of the plan is further evidence of India's efforts to strengthen disaster risk governance which included the establishment two years ago of a National Platform for Disaster Risk Reduction.

The resilience action plan has been framed broadly with the goals and targets outlined in the Sendai Framework. The framework's outcome aims to reduce the existing hazard/ disaster risks, exposure to hazards and vulnerability to the disaster, increase the preparedness and pre & Post mitigation actions, and strengthen the city's resilience and its people and the Govt.

The Sendai Global Targets has been addressed through planning towards substantially reducing:

- The disaster mortality
- The number of people directly or indirectly affected by the disaster
- Damage caused to critical infrastructure and disruption to basic infrastructure
- Increasing access to early warning systems and disaster risk information and assessment.

Chapter 2

Study Area – Shillong city, Meghalaya

2.1 Meghalaya State

Meghalaya is situated between 24°57′ and 26°10′ North latitudes and 89°46′ and 92°53′ East longitudes. The state is located in the north-eastern part of the country. It is surrounded by the Indian state of Assam to the north and northeast and by Bangladesh to the south and southwest. The state capital is the hill town of Shillong, located in east-central Meghalaya (Authority, 2016) . The three physical divisions in the state are Garo (Western), Khasi (Central) and Jaintia (Eastern) hill, divisions. The state covers 22720 km2covering 11 districts, 39 blocks and 6839 villages. The state has a total population of 29,64,007 and a population density of 132/ sq km (Census, 2011)

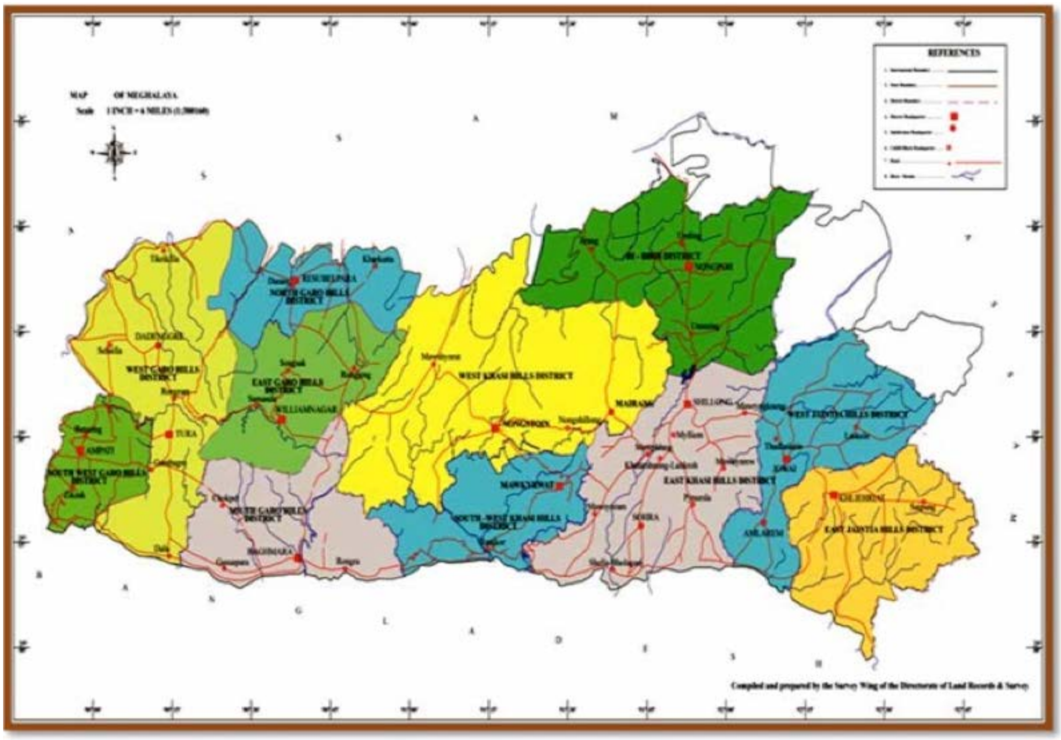


Figure 8: Meghalaya State (Meghalaya State Disaster Management Plan, 2016)

The defining physical characteristics of Meghalaya State are

- The state is a multi-hazard state and is prone to disasters like earthquakes, landslides, floods, cyclonic storms.
- The State lies in the seismically active zone; with the growth of population and unplanned infrastructure, seismic vulnerability has increased
- Remnant depressions do occur in western Meghalaya, their severity being more during monsoon season.
- Due to heavy rain, flash floods may be caused, resulting in riverbank erosion and some local damage
- Landslides generally occur during heavy rains, that is, during June to October in Meghalaya
- Shifting or Jhum cultivation, slash-and-burn or burn-and-plant method of shifting cultivation destroys not only the forest cover but also harm people living close to the forest by polluting the environment.

2.2 Shillong City Profile

Shillong, the capital city of Meghalaya, is located in the deeply dissected central upland zone of the Meghalaya Plateau. Shillong is also the most urbanized and largest city in the hill state of Meghalaya. It is also the 2nd largest city in the North-East Himalayan Region of India. The population of the city is 143,229 (Census,2011). The population growth rate over the last decade has been 7.79% (2001 Population – 132,867). The city has witnessed unprecedented population growth in recent years, primarily due to a high fertility rate coupled with heightened migration from neighbouring countries of India and across the border (Dr. Aparesh Patra and Prof. Debendra Kumar Nayak, 2007).

Indicators	Characteristics
Classification of the city	Hilly city
Location	25°34'00"N& 91°53'00"E
Area	10.36 sq km
Climate Type	Subtropical highland climate
Temperature (IMD, 2010)	Average high temperature - 20° C Average low temperature - 12°C
Rainfall	Average annual: 2,162 mm
Mean Sea Level	4,908ft above MSL

Table 2 Characteristics of Shillong City

Shillong Urban Agglomeration covers an area of 70.4 square kilometres. It includes Shillong Municipality (10.36 Sq. KM), the Cantonment (1.84 Sq. KM), and the townships of Mawlai, Nongthymmai, Madanrting, Pynthorumkhrah, Nongmynsong (Fig 1) (Tariang, 2012), covering the rest of the area.

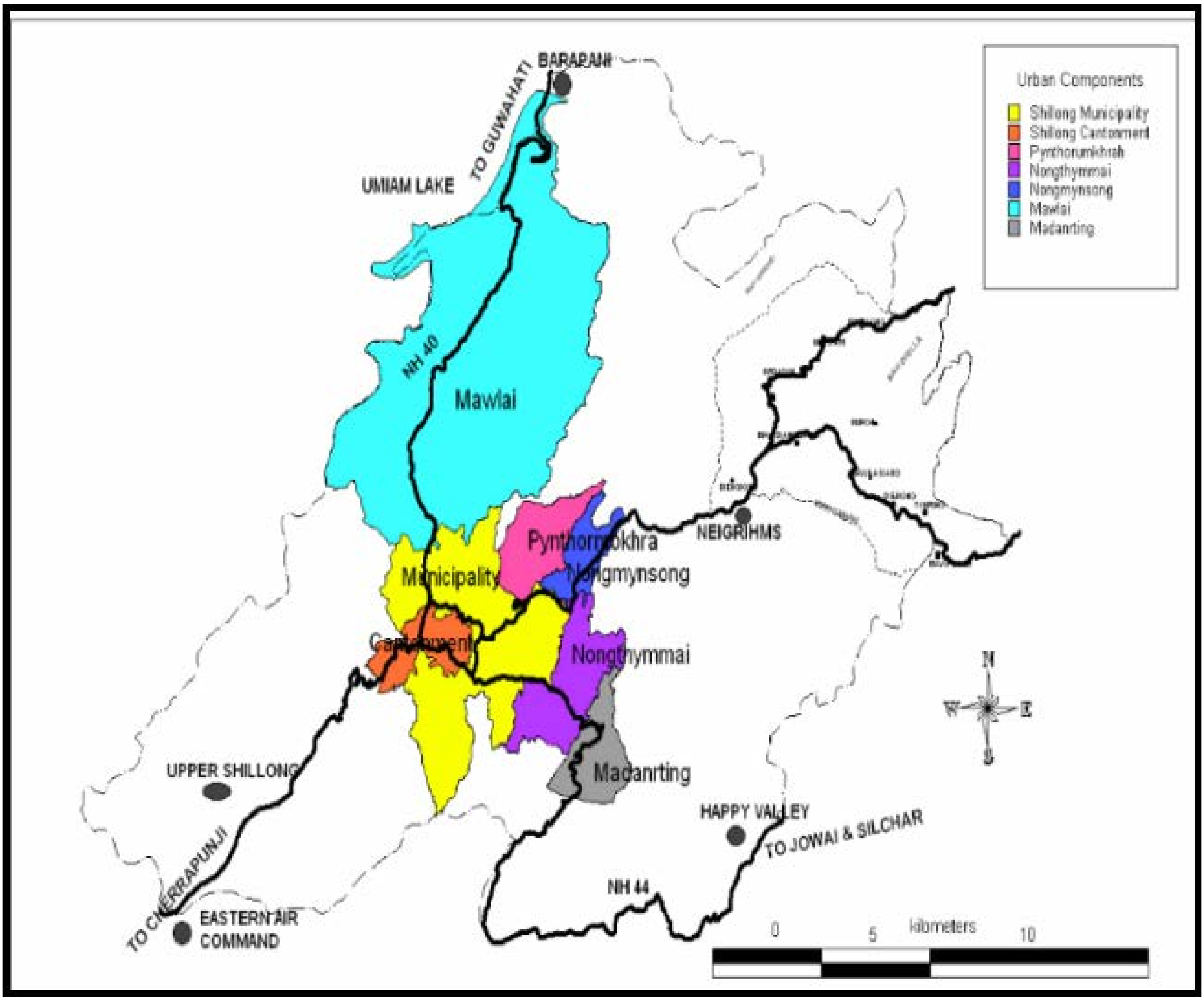


Figure 9: Shillong Urban Agglomeration (Source: CDP, Shillong)

Shillong is landlocked and situated at an altitude of 4,908ft above mean sea level. It lies in the centre of the Shillong Plateau, surrounded by hills. Shillong has a pleasant climate and is famous for its scenic beauty; it is a major tourist attraction and also the hub of education for the entire Northeast with many well-established institutions. The humid subtropical climate of Shillong is characterized by moderately warm wet summers and cool, dry winters. The average maximum and minimum temperature is around 20° C and 12° C, respectively. Shillong experiences a prolonged rainy season with intermittent rain throughout the year. Two-thirds of the rainfall occurs in the months from June to September, from the South-West monsoons. The relative humidity is highest during the rainy season (above 80%).

2.3 Hazard Exposure and Vulnerability Assessment of Shillong City

2.3.1 Hazard Exposure

Shillong city is prone to the consequences of climate change because of its geo-ecological fragility, the eastern Himalayan landscape, its transboundary river basins and its inherent socio-economic instabilities. Shillong city is vulnerable to natural hazards such as landslides, heavy rainfall, floods, and man-made disasters such as road accidents, fires, water scarcity due to rapid urbanization, and improper and uncontrolled construction. Table 3 shows the history of disasters of Shillong city (Sustainable and Disaster Resilient Urban Development; City Report- Shillong; 2015).

Type of Hazards	Year of Occurrence	Impact on				
		Area	Population	Life	Livelihood	Livestock
Extreme winds/ Thunderstorms/ cyclones	2000, 2001, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2011, 2012, 2013	Yes	Yes	-	Yes	yes
Flash Flood	1999, 2001, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2011, 2012, 2013	Yes	Yes	Yes	Yes	yes
Landslide	1999, 2001, 2002, 2003, 2004, 2005,2006, 2008, 2009, 2010, 2011, 2012, 2013	Yes	Yes	Yes	Yes	yes
Incessant Rainfall	1999, 2001, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2011, 2012, 2013	Yes	Yes	Yes	Yes	yes
Fire	1999, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013	-	Yes	Yes	Yes	Yes
Source: Sustainable and Disaster Resilient Urban Development; City Report- Shillong; 2015						

Table 3: History of Disasters in Shillong City

Hazards	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Flash Floods												
Extreme winds												
Landslide												
Thunderstorm/Lightning/ Hailstorms												

Table 4: Hazard Timeline, Shillong (MSDMA & SMC)

In Shillong, the slopes are steep, and being a part of young mountains, they are highly vulnerable to landslides. In addition, heavy rainfall makes the land more unstable and causes a massive flow of debris in every monsoon. Deforestation in the steep slopes due to human settlements and other activities results in removing vegetation cover and exposing rocks, resulting in the weathering processes. These processes all together trigger landslides. This causes severe disturbance to road transportation and communications, which have a major bearing on the availability of essential commodities and their prices and national security.

Hazard Type	Exposure
Heavy Rains	Yes
Drought	No
Landslides/avalanches	Yes
Floods	Yes
Thunderstorm/ Lightning	Yes

Table 5: Hazard Exposure, Shillong city

Shillong is home to rain-bearing clouds and is near one of the wettest places on earth - Cherrapunji. The Monsoon season in Shillong starts in June and ends around September and is accompanied by heavy rains and strong winds. Hailstorms, thunderstorms and squalls commonly occur in the city, and its citizens typically face problems during the rainy season. While rains are a relief to the water-starved city, it is also a disadvantage as weeks of thundershowers not only worsen the already dilapidated pavements but makes walking through them almost impossible. Moreover, the number of flooded streets has been rising during the monsoon season in the city. Improper and uncontrolled construction is considered the prime reason for the menace, and preventive measures should be initiated before things get out of control.
Meghalaya is projected to receive an increase in precipitation in all the districts. The western districts of Meghalaya are predicted to obtain a smaller increase in rainfall compared to the eastern districts, which are predicted to obtain a higher increase in rainfall.

There is a high variability of projected rainfall, where eastern districts such as East and West Garo Hills are projected to obtain an increase in rainfall of only about 3%. East Khasi Hills district is expected to experience an increase of 10-15% in precipitation by 2050.

2.3.2 Impact of future changes in temperature and precipitation

The all India mean surface air temperature change for the mid-term period 2040–2069 relative to 1976–2005 is projected to be in the range of 1.39–2.70 °C and is larger than the natural internal variability. This assessment is based on a reliability ensemble average (REA) estimate incorporating each RCM performance and convergence associated with less than 13% uncertainty range. All India mean surface air temperature is projected to increase in the far future (2070–2099) by 1.33 ± 0.24 °C under RCP2.6, 2.44 ± 0.41 °C under RCP4.5 and 4.44 ± 0.45 °C under the RCP8.5 scenario, respectively. (Assessment of Climate Change over the Indian Region (R. Krishnan et al, 2020) A Report of the Ministry of Earth Sciences (MoES), Government of India, 2020). The city is highly vulnerable to climatic environmental hazards, being a part of the mountain ecosystems, where extreme slopes lead to rapid changes in climatic zones over small distances. These factors impact biodiversity, water availability, agriculture, and general human well-being (Sharma et al., 2009) . The city has experienced a rapid rise in temperature over the last 50 years. The western parts of the state are projected to experience a higher increase in temperature relative to the eastern part (MoHUA, 2015). However, the variability in temperature increase is not high, with the highest increase being 1.8°C and an average increase in the range of 1.6°C. For East Khasi hills district (Shillong), the temperature increase is expected to be 1.6-1.7°C by 2050 (MoHUA, 2015).

2.4 Rapid Vulnerability Assessment

This provides a summary of the vulnerability assessment of Shillong city based on the HIGS framework.

1. SOCIO-ECONOMIC CHARACTERISTICS

Population	• 2001 Population – 132,867, 2011 Population – 143,229. Growth Rate – 7.79%
Density	• The population of Shillong forms 68% of the total urban population of the state (City Development Plan)
Slum Population	• ~ 13,825 per sq km in 2011 (Census , 2011) • 12 slum pockets, total number 2,992 inhibiting 14,458 resides and covering 10% of the city population (Census , 2011)

2. HAZARD AND EXTREME EVENTS

Temperature observed and projection	• Average maximum temperature- 20° C & Average minimum temperature-12° C
Temperature Projections	• The temperature increase is expected to be 1.6-1.7°C by 2050 (Meghalaya State Action Plan on Climate Change, 2015)
Rainfall observed trend and projections	• The average annual rainfall of Shillong is 2,162 mm • Hailstorms, Thunderstorms and Squalls are the common forms of rainfall in Shillong.
Rainfall Projections	• The East Khasi Hills district is expected to experience an increase of 10-15% in precipitation by 2050. (Meghalaya State Action Plan on Climate Change, 2015)
Extreme events: Urban Floods/ Flash Floods	• Incidences of waterlogging in the city are 25%, with the numbers increasing during monsoons • August 2014, Incessant rain over 24 hrs caused a flash flood in the city .

Landslides

- In 2014, torrential rain triggered a landslide that killed almost eight people in the Mawbah area of Shillong (Times of India, Shillong, 2014).
- In 2015, 12 people were killed in the landslides in Meghalaya (NDTV India, 2015).

Water Scarcity

- With the rapid growth of urbanization, citizens face a shortage of water in the city.
- Water scarcity in Shillong is related to the problem of water quality as well as water quantity.
- Over the years, a declining trend in rainfall has also been discernible.

INFRASTRUCTURE STATUS (AMRUT, NIUA, 2016-17)

Water Supply

- The primary source of water supply for Greater Shillong is River Umium.
- In 2016-17, almost 77% of the households (HHs) had water supply connection.
- The per capita water supply is low at 78lpcd.
- The water connections are not metered, and only 12% of the water services cost is recovered.

Sewerage

- Almost 94% of the HHs in the city have individual & community toilet coverage.
- 6.47% of HHs have no facilities, hence resort to open defecation
- Under Swachh Bharat Mission, 40 individual toilets, 7 community toilets and 115 public toilets are being proposed
- No sewage treatment plant, all the house sullage (kitchen and bathroom wastewater) drains either into the River Umshyrpi in the south or the Um Khrah in the north.

Solid Waste Management

- 159 MT of municipal solid waste is produced per day, 0.4 kg of waste per capita per day. The major solid waste generation sources are households (56%), markets(23%), hotels & restaurants(7%), construction waste(2%), and street sweeping(7%)
- In the SMB area, 46% of the waste generated is collected. In comparison, outside the SMB area, the figure is only 32%, and for the entire GSPA (Greater Shillong Planning Area), the percentage of garbage collected works out to about 41%.
- Presently garbage collected is disposed into the gorges of the trenching ground situated at MAWLAI on Shillong Guwahati Road (Shillong Municipal Board, 2018)

Stormwater Drainage

- The drains run for 148.91 km across the city and drain into the Umkhrah and Umshyrpi river
- At present (2016-17), Stormwater drainage network coverage is less than 75% of the city, the incidence of sewerage mixing in drains is almost 100%

Transportation	• The total road length of Shillong is 356 km with a road density of 2.05 km/sq km (Shillong City Development Plan). • NMT has not being stressed upon in the city Comprehensive Mobility Plan (CMP) due to undulating topography & operational constraints
Power	• The average electricity consumption in a residential area is 300 units /house/day and in commercial areas, it is 450 units / shop/day • The agencies responsible for the supply, management and distribution of the electricity in the city are: (1) North Eastern Regional Electricity Board, Shillong; (2) Meghalaya State Electricity Board, Shillong and (3) Neepco
Housing	• Out of total households in Shillong city, about 46 % of the houses are made of Concrete, followed by, Wood and Burnt Bricks. • Out of the 65 Slums in Shillong UA, except for two slums, the rest are private land (Ministry of Housing and Urban Poverty Alleviation, GOI, 2015). • Housing for all Plan Of Action for Shillong indicate 2296 housing demand from EWS & LIG category under BLIC, CLSS and AHP component (Smart City Shillong proposal 2016)
4. Governance	
Administrative Units assigned to address climate change	• Shillong Municipal board is responsible for service delivery; this includes water supply, solid waste management • East Khasi Hills District Commissioner office is quite active in the area of Disaster Risk Reduction and disaster management planning • Meghalaya Basin Development Authority, Meghalaya Disaster Management Authority and state government are important stakeholders,
The willingness of the city to address Climate Change	• The Forest and Environment Department, Government of Meghalaya, along with the Meghalaya Basin Development Authority with Technical Support from GIZ, organized the 'Expert Consultation Prioritizing Actions under Meghalaya's State Action Plan on Climate Change (SAPCC)' in May 2013 and Meghalaya State Action Plan on Climate Change was developed in 2015. • The local government, including Shillong Municipal Board (SMB) and district unit, is implementing Urban Risk Reduction(URR) and DRR programmes with support from UNDP. This also involves integrating risk reduction into urban development programmes while assessing risk and vulnerabilities and strengthening Building codes, By-laws and development control regulations (DCR). • ULB and UNDP are also developing ward-level risk assessments, including understanding the existing early warning systems and identifying formal & informal mitigation actions and recommendations.

Table 6: Vulnerability profile of Shillong city

2.5 Physical Vulnerability

2.5.1 Urban Population

Population growth especially increased population density and urbanization, increases vulnerability to disasters (Charles Perrow, 2007). The severity of any disaster is usually related to the population it affects. The impact of natural disasters is always worse if the proportion of the population affected is significant. The high population density in any city makes the impact of the disaster disproportionately worse.

Shillong became the capital of the new state of Meghalaya in 1972, and before that, it remained the capital of undivided Assam. After Independence, Shillong witnessed the vertical expansion and large scale immigration. “Shillong is a ‘potential satellite town growth pole’ in terms of urban expansion and potential township development” (Shukla, S. P., 1997). “Shillong has witnessed a phenomenal urban expansion in the last three decades” (Sengupta, S., Dhar, B., 2004)-. There have been profound changes in land use and land cover of Shillong in the years from2006 to 2011(Khardewsaw, 2013). Shillong city is divided into 27 wards. Figure 2 shows ward wise population density as per the census 2011. The population of the city is 143,229 (Census, 2011). The Shillong Municipal Board has a population of 143,229, of which 70,135 are males while 73,094 are females, as per a report released by Census India 2011. Shillong is also the most urbanized and largest city in the hill state of Meghalaya. The population growth rate over the last decade has been 7.79% (2001 Population – 132,867). The details of the 27 wards population and population density has been provided in the table below. The highest Population density is observed in ward no. 19, Mawprem.

Ward no.	Ward name	Population	Area	Density (perKM2)
Ward No. 1	Laitumkhrah	11537	0.54	21528.94
Ward No. 2	Laitumkhrah	3266	0.41	7911.75
Ward No. 3	Laitumkhrah	5437	0.67	8145.51
Ward No. 4	Laitumkhrah	2753	0.36	7706.40
Ward No. 5	Malki	4908	0.52	9471.36
Ward No. 6	Malki	4888	0.20	24366.84
Ward No. 7	European Ward	4891	0.57	8608.83
Ward No. 8	European Ward	6009	0.85	7044.38
Ward No. 9	Police Bazar	2145	0.12	17308.41
Ward No. 10	Jail Road	5766	0.24	24509.92
Ward No. 11	Jail Road	4863	0.78	6197.24
Ward No. 12	Mawkhar	2797	0.13	22233.26
Ward No.13	Mawkhar	5337	0.17	32273.14
Ward No.14	Jaiaw	3032	0.09	35318.69
Ward No.15	Jaiaw	3838	0.28	13522.47
Ward No.16	Jaiaw	4067	0.25	16212.45
Ward No.17	S.E.Mawkhar	3270	0.14	24017.99
Ward No.18	S.E.Mawkhar	3875	0.13	29874.58
Ward No.19	Mawprem	4556	0.10	45365.19
Ward No. 20	Mawprem	10613	0.59	18059.08
Ward No. 21	Mawprem	14009	0.49	28871.25
Ward No. 22	Kench’s Trace	2973	0.16	18177.86
Ward No. 23	Kench’s Trace	8161	0.55	14862.29
Ward No. 24	Laban	3568	0.14	25539.97
Ward No. 25	Laban	5218	0.19	27376.68
Ward No.26	Lumparing	6319	0.63	10011.02
Ward No. 27	Lumparing	5133	0.91	5637.39

Table 7: Shillong Municipal Board Ward-level population | Source: Town Directory of Census, 2011, ward area calculated from Shapefiles from SMC

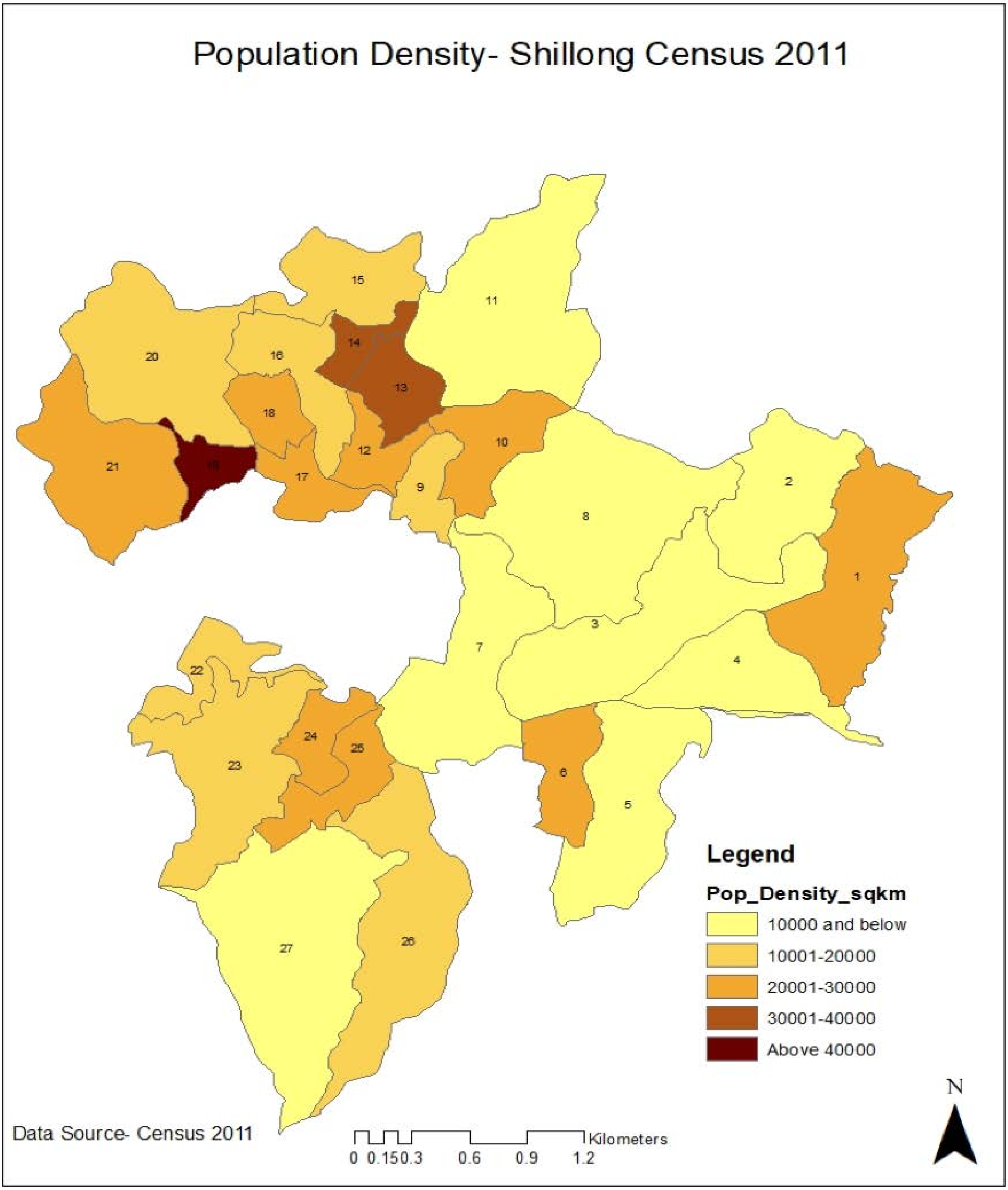


Figure 10: Ward Wise Population Density Map of Shillong

The per cent of the population in Shillong Municipality has been higher than the percentage of the urban population in India from 1961-1981, compared to the data by the census of India (Table 3). After 1991, the population rate declined; however, during this time, the population of the neighbouring districts increased. The growth of population during 1991-2001 within the Shillong Municipality area has been significantly less. The five smaller census towns within the Shillong UA has grown considerably during this period which has contributed to the overall growth of Shillong UA.

Census year	Urban Population in million- India	Percent Urban- India	Shillong Municipal Board Population	Percent Urban-Shillong
1961	78.94	17.97	72438	24
1971	109.11	19.91	87659	21
1981	159.46	23.34	109244	25
1991	217.18	25.72	131719	21
2001	286.12	27.86	132876	1
2011	377.10	31.16	143229	8

Table 8: Urban Population India and Shillong | Source: Census of India - respective censuses (www.censusindia.gov.in)

Shillong City has shown a gradual increase in its population growth rate from 1901 to 1991. However, the growth rate had decreased to a mere 1% from 1991-2001 and remained at 8% in 2011. The population growth rate is low when compared to India's urban population, which is at 31% (2011).

Year	Persons	Decadal Variation (+)	Decadal Variation(PC.)
1901	9621	-	-
1911	13639	4018	42%
1921	17203	3564	26%
1931	26536	9333	54%
1941	38192	11656	44%
1951	58512	20320	53%
1961	72438	13926	24%
1971	87659	15221	21%
1981	109244	21585	25%
1991	131719	22475	21%
2001	132876	1157	1%
2011	143229	10353	8%

Table 9: Data of past decades (1901-2011) for Shillong

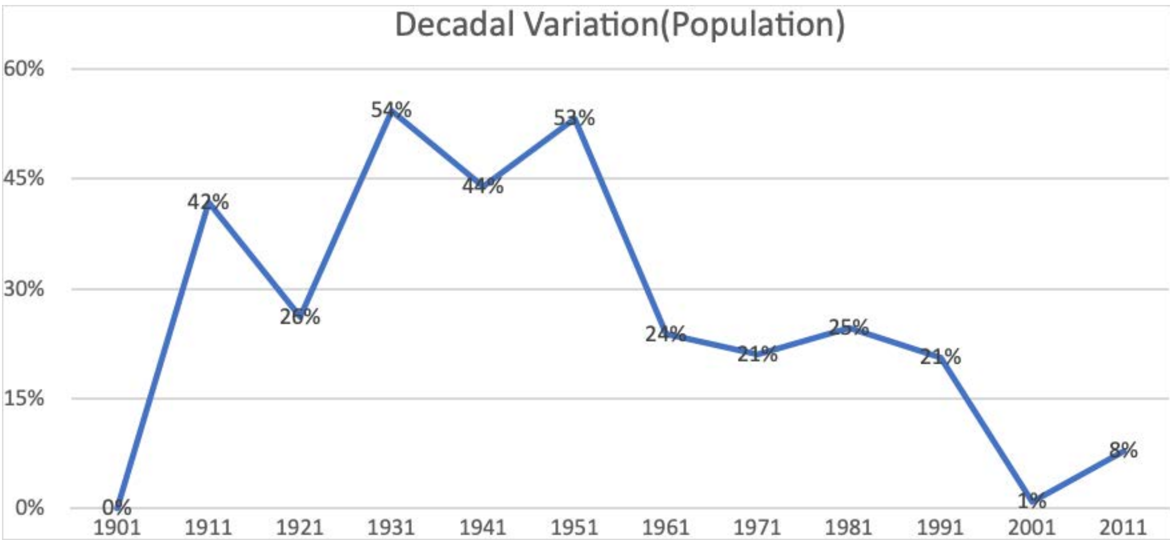


Figure 11: Decadal variation in Shillong Population (1901-2011)

the above graph (fig. 11) shows a sharp decline in the urban population of Shillong Municipal areas since 1991. As documented in the ' Meghalaya State Development Report[1], growth was recorded in the small census towns within the Shillong UA recorded considerable growth rate during 1991-2001, due to inter-district population flow; however, the Shilling MB area experiences lower growth rate.

2.6 Socio-economic Vulnerability

2.6.1 Slum Population

Rapid urbanization, industrialization and the negative consequences of urban pull result in the formation of slums, which in the metropolitan cities create conditions that can turn a hazard into a disaster. In the absence of basic facilities, the slum population is the most vulnerable group in times of disaster. The slum population in Indian cities has increased during 2001-11; nearly 17.34 % of the urban population lives in India's slum and slum-like conditions. (MoHUA, NBO, 2013).

Slums are defined as mainly those residential areas where dwellings are unfit for human habitation by reasons of dilapidation, overcrowding, faulty arrangements and designs of such buildings, narrowness or faulty arrangement of streets, lack of ventilation, light, sanitation facilities or any combination of these factors, which are detrimental to safety, health and morals.

Source: Primary Census Abstract for Slums, India

According to the Census 2011, in India, Shillong city has over 2992 slums (spread over 12 pockets) and scattered settlements in which a population of 14,458 resides across private and public land. This is around 10.09% of the total population. However, the Rajiv AawasYojnasurvey in 2015 addresses 13,120 Slum households, with 42%notified slums. Shillong Municipal Board constitutes 5426 no. of slums.

Shillong, one of the fastest-growing Himalayan cities, has noticed an increase in slums due to accelerated population and unplanned haphazard development. According to the Meghalaya State Development Report, 2008, "Slums have emerged in the state's urban areas purely because of lack of infrastructure. Most of the slum pockets are located in low-lying and water-logged areas amid poor sanitary conditions and unhygienic surroundings."

[1]*http://megplanning.gov.in/MSDR/urban_development.pdf*

Chapter 3

Hazard Risk Assessment – Landslides

3.1 Introduction

3.1.1 Definition

Landslides cause loss of life and infrastructure. Landslide is the movement along the slope of the mass of rock, earth or debris (D.M.Cruden, 1991), occurring when the slope changes from a steady to an unsteady state (A Chawla et al, 2018) (A Chawla et al, 2018)

The term "landslide" now includes a broad range of motions such as falling, sliding and flowing under the influence of gravity, all of which dislodges earth material. In the hilly terrains of India, including the Himalayas, landslides have been a major and widely spread natural disaster. They damage life and property and occupy a position of major concern. (NIDM, 2012)

Landslides are a mass movement of rock, soil, or debris material forming a slope (natural or engineered) towards the lower and external part of the slope, along a defined sliding surface.

Over 4,800 fatal landslides were recorded worldwide from **2004 to 2016** (University of Sheffield , 2018). Landslides around the world killed more than 56,000 people during the period, a majority of which involved a single slope, according to the study based on the Global Fatal Landslide Database (GFLD). At least 700 of these fatal landslides were caused by construction works, illegal mining and unregulated hill-cutting (Srishti Choudhary, 2018).

3.1.2 Landslide Classification

Based on the landslide morphology and the process of mass failure, landslides have been classified into five types: Fall, Topple, Slide, Spread, Flow and Subsidence (NIDM, 2012).

- Fall: is very rapid to an extremely rapid movement which starts with the detachment of material from steep slopes such as cliffs, along a surface on which little or no shear displacement takes place
- Topple: involves overturning of material. It is the forward rotation of the slope mass about a point or axis below the centre of gravity of the displaced mass
- Slide: movement of material along a recognizable shear surface
- Spread: Sudden movement on water-bearing seams of sand or silt overlain by homogeneous clays or loaded by fills.
- Flow: is a landslide in which the individual particles travel separately within a moving mass
- Slump: type of rotational failure on slopes. The trees bend or fall back towards the slope
- Creep: Very slow rates of slope movements, usually a few millimetres per year

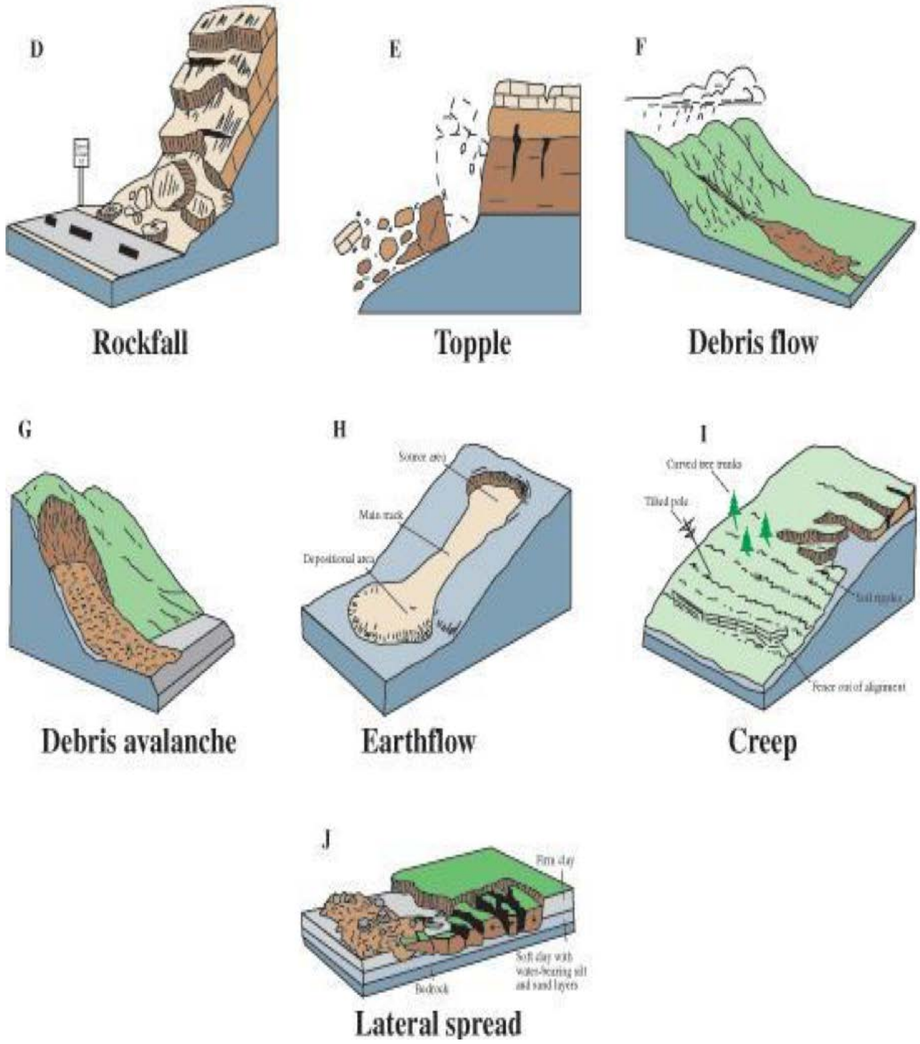


Figure 12: Slides Typology, NIDM, 2012

3.2 Landslides in India

According to a Sheffield University study (published in the European Geosciences Union journal, Natural Hazards and Earth System Sciences, August 2018), India is among the most-affected countries among the 4,800 fatal landslides which occurred globally from 2004 to 2016, accounting for at least 28% of such events over last 12 years (University of Sheffield , 2018).

Landslides and avalanches are among the major hydro-geological hazards that affect large parts of India besides the Himalayas, the Northeastern hill ranges, the Western Ghats, the Nilgiris, the Eastern Ghats and the Vindhyans, in that order, **covering about 15 % of the landmass.** The Northeastern region is badly affected by landslide problems. Landslides in the Darjeeling district of West Bengal and those in Sikkim, Mizoram, Tripura, Meghalaya, Assam, Nagaland and Arunachal Pradesh pose chronic problems, causing recurring economic losses worth billions of rupees (NDMA, 2013).

According to the GSI in India, about 0.42 million sq. km or 12.6% of land area, excluding snow-covered areas, is prone to landslide hazard (GSI, 2020). Out of this, 0.18 million sq. km falls in North East Himalaya, including Darjeeling and Sikkim Himalaya; 0.14 million sq. km falls in North West Himalaya (Uttarakhand, Himachal Pradesh and Jammu & Kashmir); 0.09 million sq. km in the Western Ghats and Konkan hills (Tamil Nadu, Kerala, Karnataka, Goa and Maharashtra) and 0.01 million sq. km in Eastern Ghats of Aruku area in Andhra Pradesh (GSI, 2018).

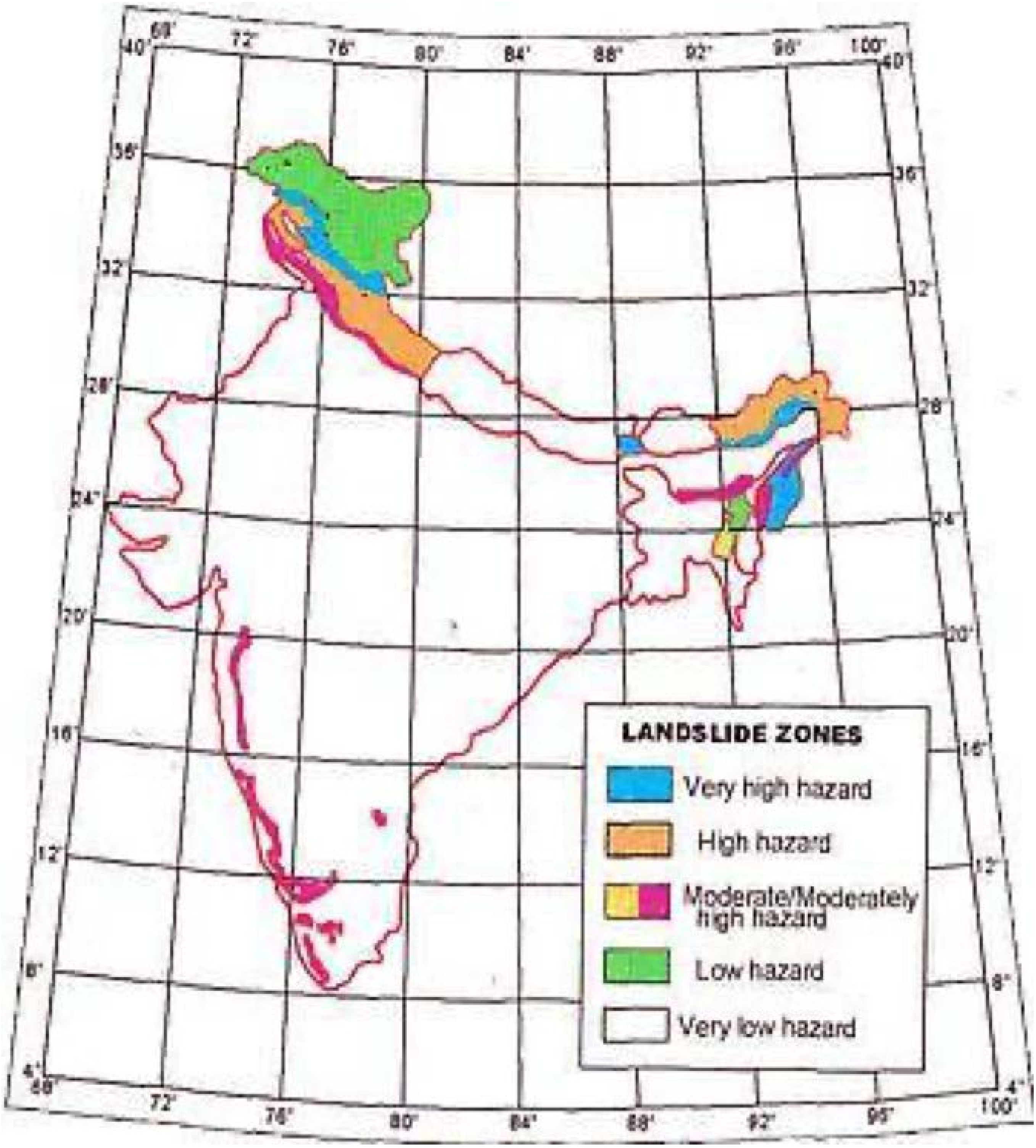


Figure 13: Landslide Zone Maps, NDMA

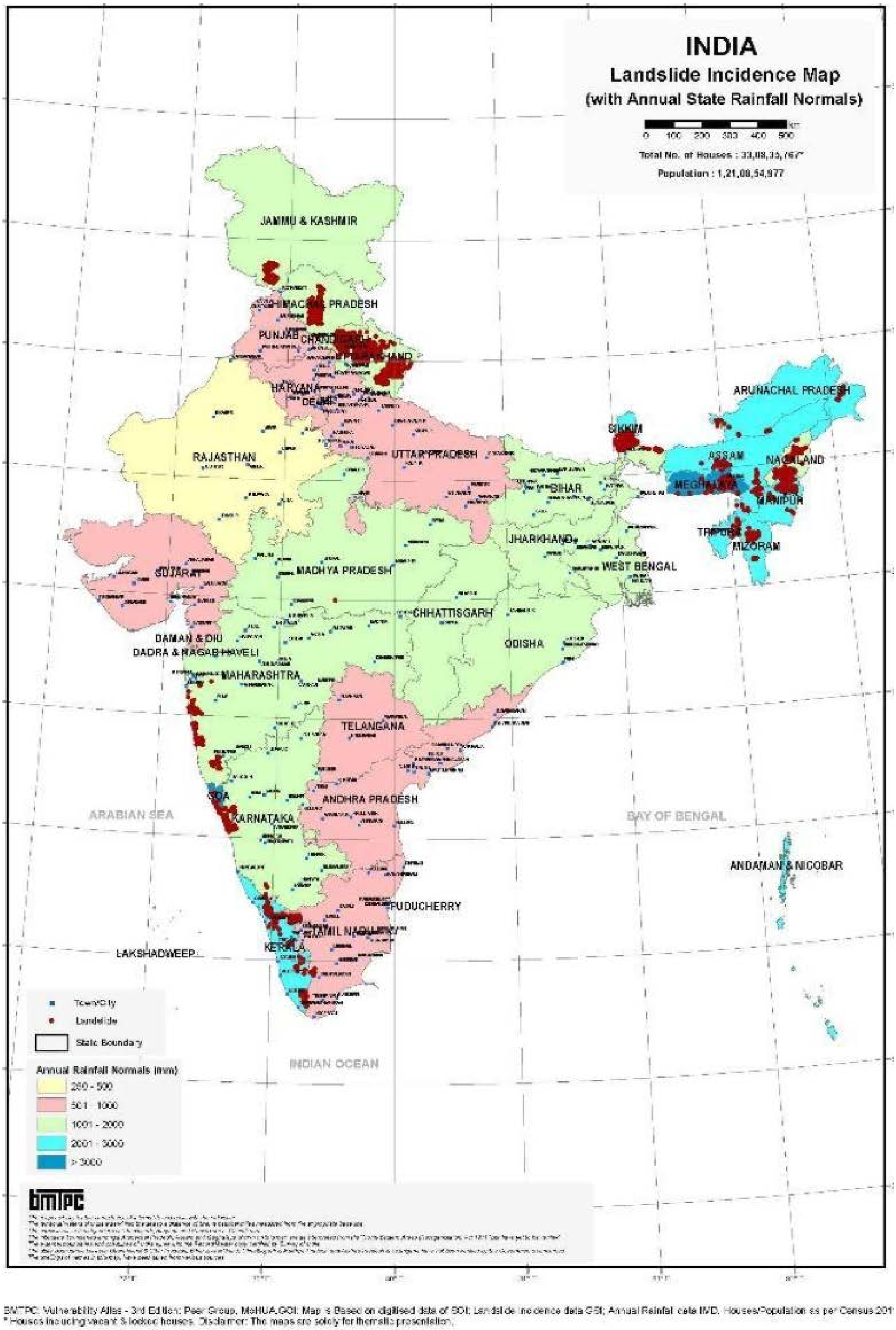


Figure 14: Landslide Incidence Map, BMTPC, MHUA &NIDM, 2019

Source: Vulnerability Atlas of India, Third Edition, 2019, BMTPC, MHUA, GoI& NIDM (NIDM, 2014)

3.2.1 Landslides in Meghalaya

Landslides are a natural & common occurrence in a tectonically fragile and sensitive mountainous terrain like the Himalayas (Dubey, C.S., Chaudhry, M., Sharma, B.K. et al., 2005). Meghalaya's terrain makes it very prone to Landslides. In Meghalaya, around 42 people died due to landslides in 2014. (Revenue and Disaster Management, Govt of Meghalaya) Many factors are responsible for slope instability, but the main controlling factors are rainfall, seismic activities and anthropogenic activities (Harjeet Kaur, Srimanta Gupta, Surya Parkash, Raju Thapa, Arindam Gupta & G. C. Khanal, 2019) . Very few attempts have been made to study the landslides and flash floods in Meghalaya in general and Shillong in particular. (Agarwal, 1994).

Year	Region	Impact
2010	Ri Bhoi district, Meghalaya	The economic loss of ~Rs.60 Lakh
28 July 2007	Guwahati and West Garo Hills, Meghalaya	13 killed, 75000 displaced
7th May 2018	Landslide incidence at Sonapur, East Jaintia Hills District, Meghalaya (7th May 2018)	The landslide reportedly blocked 10m stretches of the important road corridor (NH-6) connecting Shillong with the Barak Valley of Assam, Mizoram and Tripura for more than 12 hours until it was finally opened for traffic.
17th June 2017	Landslide incidence in Tharia village, Ri Bhoi District, Meghalaya (17 June 2017)	Five persons were reported dead, including two minors and three adults, and five tin-roofed hutments were completely buried under the debris.
30 September 2014	The Garo Hills region witnessed flash floods and landslides	Numerous casualties
23 September 2014	Mawbah under Mawprem area in Meghalaya's East Khasi Hills District.	Eight persons, including a pregnant woman, were buried alive under the debris
20th August 2009	Between Jorabat and Sonapur	Surface communication between lower and upper Assam and Meghalaya was disrupted since 6 am of 20th August 2009 as landslide triggered by heavy rains blocked the NH-37
28th June 2010	Meghalaya police's CID complex, Shillong, Meghalaya	One person killed and seven injured
12th May 2010	Landslides at Tongseng (Narpuh) and Sonapur on the National Highway	

Table 10: Landslides in Meghalaya State source of data required | Source: Geological Survey of India

3.3 Landslides in Shillong city

Shillong city is less prone to landslides than its neighbouring areas, including the approach roads to the city. The city experiences most landslides during the monsoon that causes damages to houses, roads, and sometimes agricultural land. However, the potential of earthquake-triggered landslides cannot be ruled out, as the region has a potential for very strong earthquakes. Only four historical landslides could be identified (RMSI, 2019). Out of these, there is one natural landslide, which lies on the left bank of Umshirpi River near Lumlyer. The remaining three landslides happened due to human interference. However, the potential of earthquake-triggered landslides cannot be ruled out, as the region has a potential for large earthquakes (RMSI, 2019) . Shillong lies in Seismic zone V and experiences frequent tremors.

3.3.1 Causes of Landslides

There are natural causes like rainfall, earthquake, loss of soil structure, and man-made causes like deforestation, construction, cultivation, and blasting to make the slope unstable. Landslides usually occur when the soil resistance deteriorates in the presence of stresses generated due to several reasons. However, these conditions are site-specific and vary from one geo-environmental setting to another (Gupta, S. K., Shukla, D. P., & Thakur, M., 2018). In the Himalayan mountain region, especially in Nepal and India, many of the fatal landslides triggered by construction occurred on road-building sites in rural areas. Landslides triggered by hill-cutting are a problem in rural areas, where many people illegally collect material from hillslopes to build homes.

During the monsoon months, the **rain coupled with frequent earthquake tremors often causes landslides in the Shillong** area. In areas with active developmental actions, the frequency of landslides depends on anthropogenic changes and the essential structures (Ashok Kumar Sharma et al, 2011).

In the recent past, landslide vulnerability has increased due to unplanned and unscientific development, deforestation, choking and blocking natural drains, poor road construction, encroachments on steep hill slopes and unstable slopes. Some of the localities, which have experienced landslides in the recent past, include Madanriting (2000), Nongrimbah (2007), Lawsohtun (2007), Happy Valley (2007), Lumsohra, Laitumkhrah (2008), Mccabe Road, Bethesda, Arbuthnot Road, Wahkynrud, Raid Laban, Um Saw, Lumparing, Jackson Trace Road, MES. Road, and Sericulture farm (Meghalaya Urban development Department, 2016). According to GSI, there is only one natural landslide within the city, which lies on the left bank of the Umshirpi River near Lumlyer. The remaining landslides occurred due to human interference.

Type of Hazards	Year of Occurrence	Impact on				
		Area	Population	Life	Livelihood	Livestock
Landslide,.	1999, 2001, 2002, 2003, 2004, 2005,2006, 2008, 2009, 2010, 2011, 2012, 2013	Yes	Yes	Yes	Yes	yes
(Source: Parikh et al., 2015)						

Table 11: History of Disasters in Shillong City

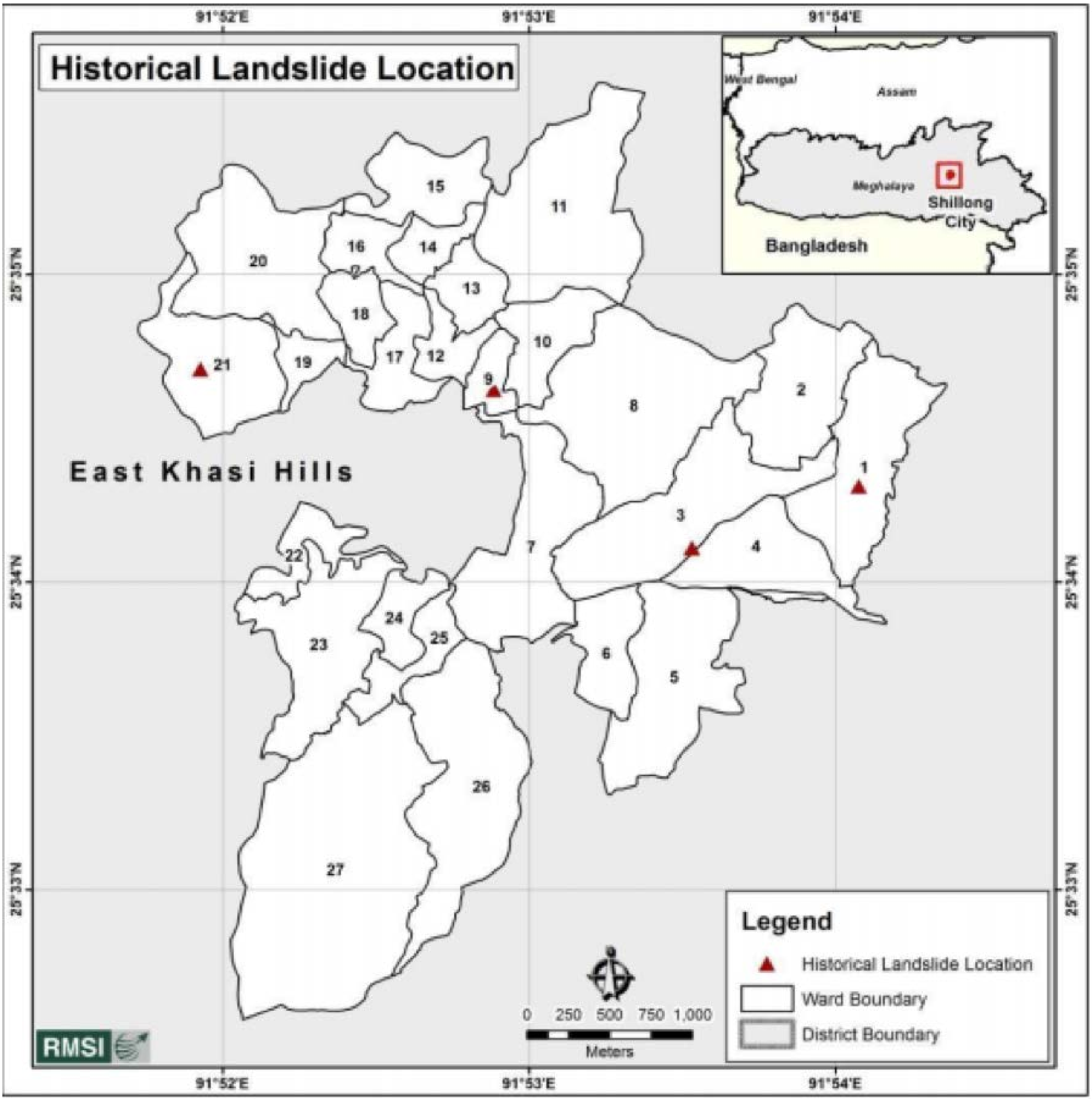


Figure 15: Location of Landslide events in Shillong(CDMP, 2018)

3.4 Landslide Susceptible Zonation

3.4.1 Introduction

Landslide susceptibility is the likelihood of a landslide occurring in an area depending on local terrain conditions, estimating "where" landslides are likely to occur. (Couture R, 2011) reported that landslide susceptibility zoning is the 'division of land into somewhat homogeneous areas or domain and their ranking according to the degrees of actual or potential landslide susceptibility, hazard or risk'.

3.4.2 Existing Landslide Vulnerability Assessment

Multi-Hazard Risk and Vulnerability Assessment Report and risk atlas of Shillong City (Meghalaya) were carried out as part of the ongoing GOI-UNDP Disaster Risk Reduction (DRR) Programme to strengthen the institutional structure to undertake disaster risk reduction activities at various levels and to develop preparedness for recovery. The report provides findings of hazard mapping and analysis of key natural hazards the city is exposed to, namely– earthquake, flood, landslide, thunderstorm (associated with strong wind, lightning, hailstorms and cloudbursts), cold wave, heat-wave, fire, and climate change impact on hydro-meteorological hazards

In GIS analysis, the landslide susceptibility map is directly overlaid with exposure data, and all exposure that falls within the high hazard zone is considered to be at high risk (worst case scenario)
Mapping methodology has not been clearly stated in the document.

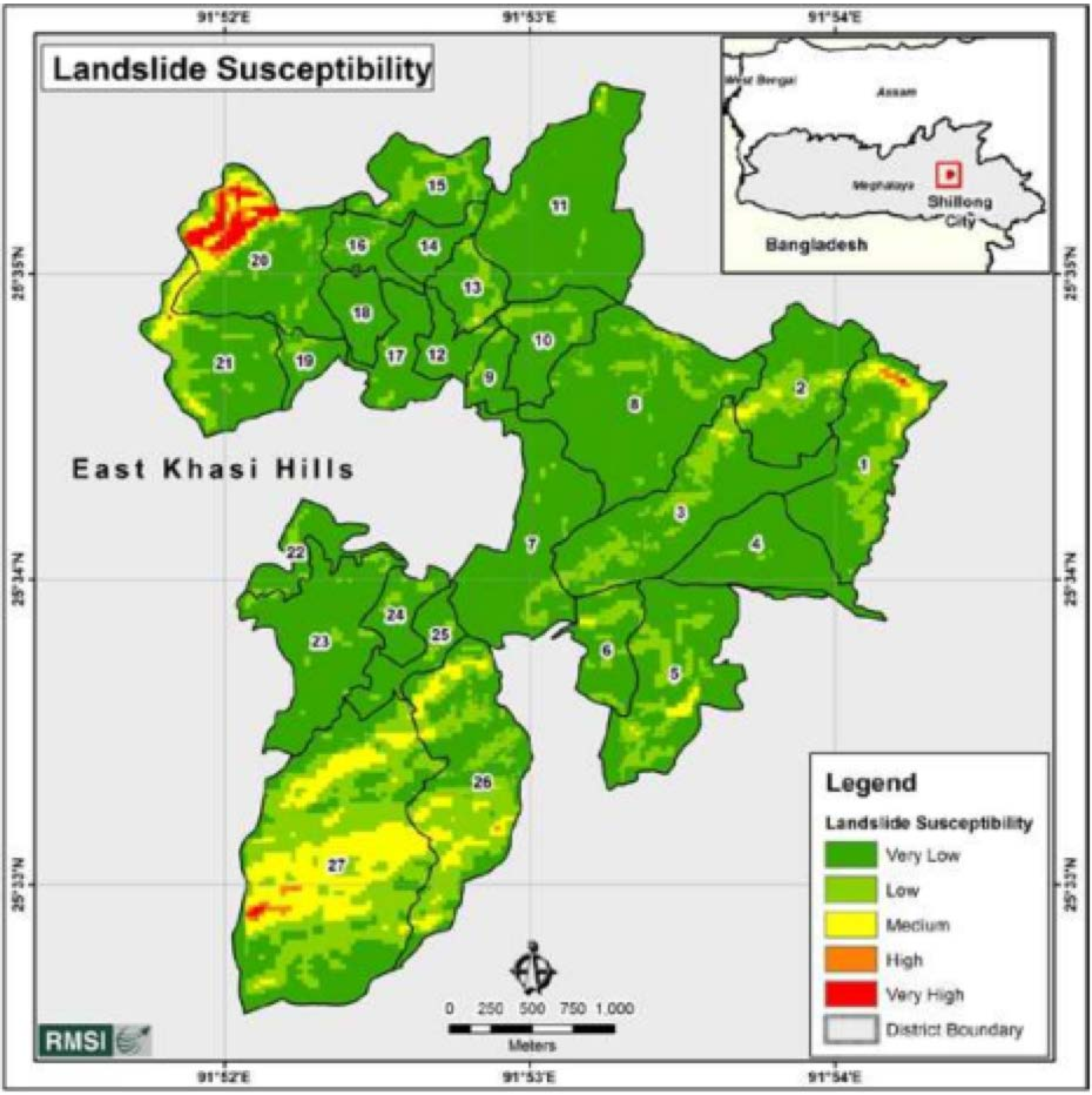


Figure 16: Landslide susceptibility map of Shillong | Source: CDMP, Shillong 2018

3.4.3 Current Study

To map the landslide susceptible zones, slope maps, land inventory maps, land lineament, Land-use Land-cover, Elevation and Aspect maps were developed on a scale of 1: 4000, and the maps are overlaid. Weightage has been given to each aspect to procure highly susceptible areas and those with very low susceptibility to landslides. **GIS-based Multicriteria Decision Analysis (MCDA) technique** used to develop cadastral maps for a scale of 1:4000 and map the hazard/disaster wise vulnerable zones of the Shillong urban agglomerations.

3.4.4 Methodology

There are a good number of **multi-criteria based hazard zonation techniques** presently being used worldwide. This project attempts to demonstrate the applicability and strength of GIS-based Analytical Hierarchy Process (AHP) with criteria such as Land-use/ Land cover, slope, Aspect, Elevation, Landslide Inventory buffer, Lineaments buffer, Lithology/ Geology, Soil Stability, Drainage Density, Isoseismal, Structural buffer, Soil, Building Density and Geomorphology. for generation of high-resolution Multi-Hazard susceptibility maps for Shillong Agglomeration.

The **Analytical Hierarchy Process (AHP**) is a problem-solving system and a methodological technique for representing the aspects of each problem (Saaty and Vargas, 1991). There are different types of AHP methods. Amongst them, the Rating methods have been chosen for this project. The rating method requires the decision-maker to estimate weight based on a predetermined scale; e.g. 0 to 100 can be used (Easton, 1973). In this method, a score of the highest rate is assigned to the most important criteria. For the Susceptibility map, it is necessary to give some score to each of the criteria or layer as per their suitability. A matrix of calculation has been done to normalize the weight. While normalizing the weight, it should be careful that the sum of the normalized weight comes as 1. In this method, all the raster criteria were reclassified and converted to vector layers. The class weight has been given to each class of individual vector layers according to their importance. The final susceptibility map was prepared by the following formula:

Landslide Susceptibility Map= ∑ [Criteria map * Weight]

For Mapping of landslide susceptibility, **seven criteria** were selected. These principal criteria are Slope, Aspect, LULC, Elevation, Lineament Buffer, Lithology, Geomorphology and Landslides inventory buffer

Ranking of all criteria has been done based on their susceptibility to the landslide. Here rank 10 indicates the maximum susceptibility, while rank 1 indicates the minimum susceptibility. All the layer rank and class weight have been given based on the Bureau of Indian Standard (BIS) format, reviewing different literature of the particular area and taking experts' choice for each criterion of the different susceptibility. To get the final susceptibility zone for two cities, different layers have been used and given the rank of each class of the layers based on susceptibility to different hazards. Weight to each factor has been assigned based on importance and the analytical hierarchy approach.

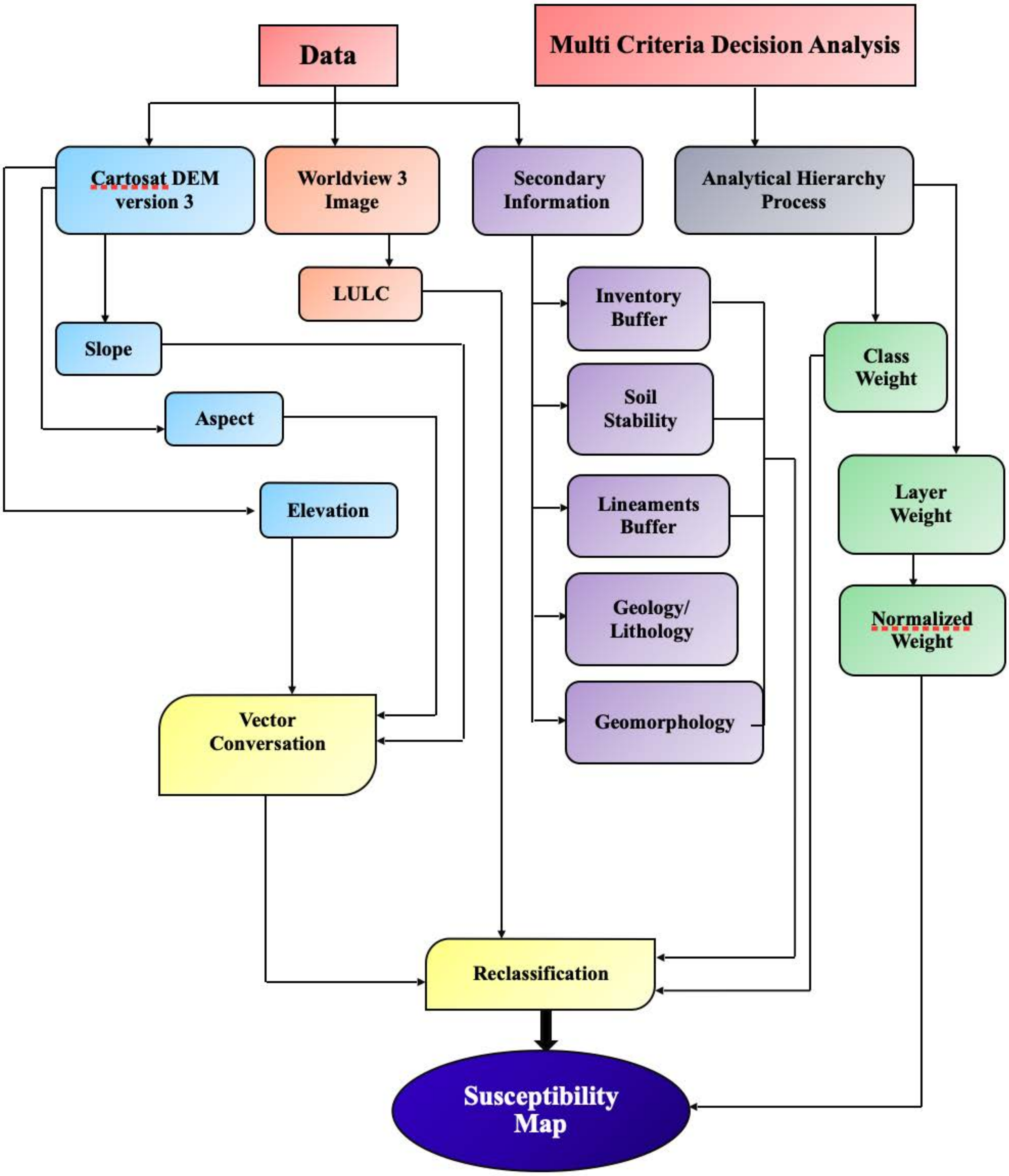


Figure 17: Hazard Susceptibility Mapping Methodology

Source : NESAC

3.4.5 Slope

The slope is one of the main parameters in the slope stability analysis (Lee and Min, 2001) (Cevik and Topal, 2003) (Yalcin, 2008). The slope angle directly affects landslides; thus, it is used in preparing landslide susceptibility maps. In some recent studies, this parameter has been considered the most important factor in landslide susceptibility mapping. The slope map was prepared using Cartosat version 3 DEM in Arc GIS 10.3 software. For preparing a multi-hazard map of Shillong, the slope map was divided into five slope categories: very low (0-70), low (7.1o-14o), medium (14.1o-21o), high (21.1o-35o) and very high (>35o). The highest slope of the study area is 81°.

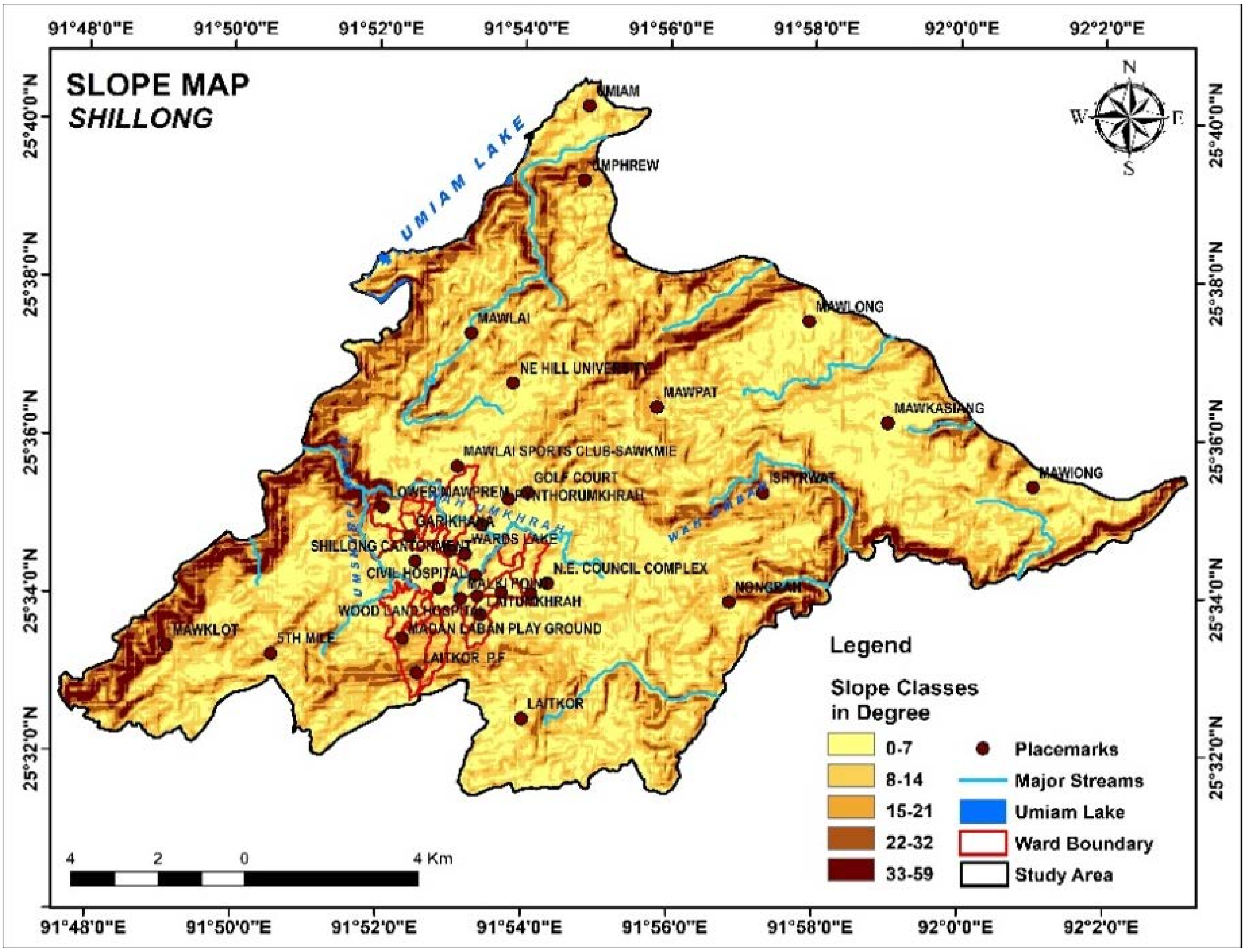


Figure 18: Slope Map, Shillong
Source: NESAC

3.4.6 Aspect

Aspect is also considered an important factor in preparing multi-hazard maps (Cevik and Topal, 2003); (Lee, 2005); (Yalcin and Bulut, 2007); (Galli et al, 2008) Aspect associated parameters such as exposure to sunlight, drying winds, rainfall (degree of saturation), and discontinuities may affect the occurrence of landslides (Suzen and Doyuran, 2004); (Komac Marko, 2006) The association between aspect and landslide is shown with aspect maps. Aspect regions are classified in nine categories according to the aspect class as; flat (−1°), north (0°–22.5°; 337.5°–360°), northeast (22.5°–67.5°), east (67.5°–112.5°), southeast (112.5°–157.5°), south (157.5°–202.5°), southwest (202.5°–247.5°), west (247.5°–292.5°), and northwest (292.5°–337.5°).

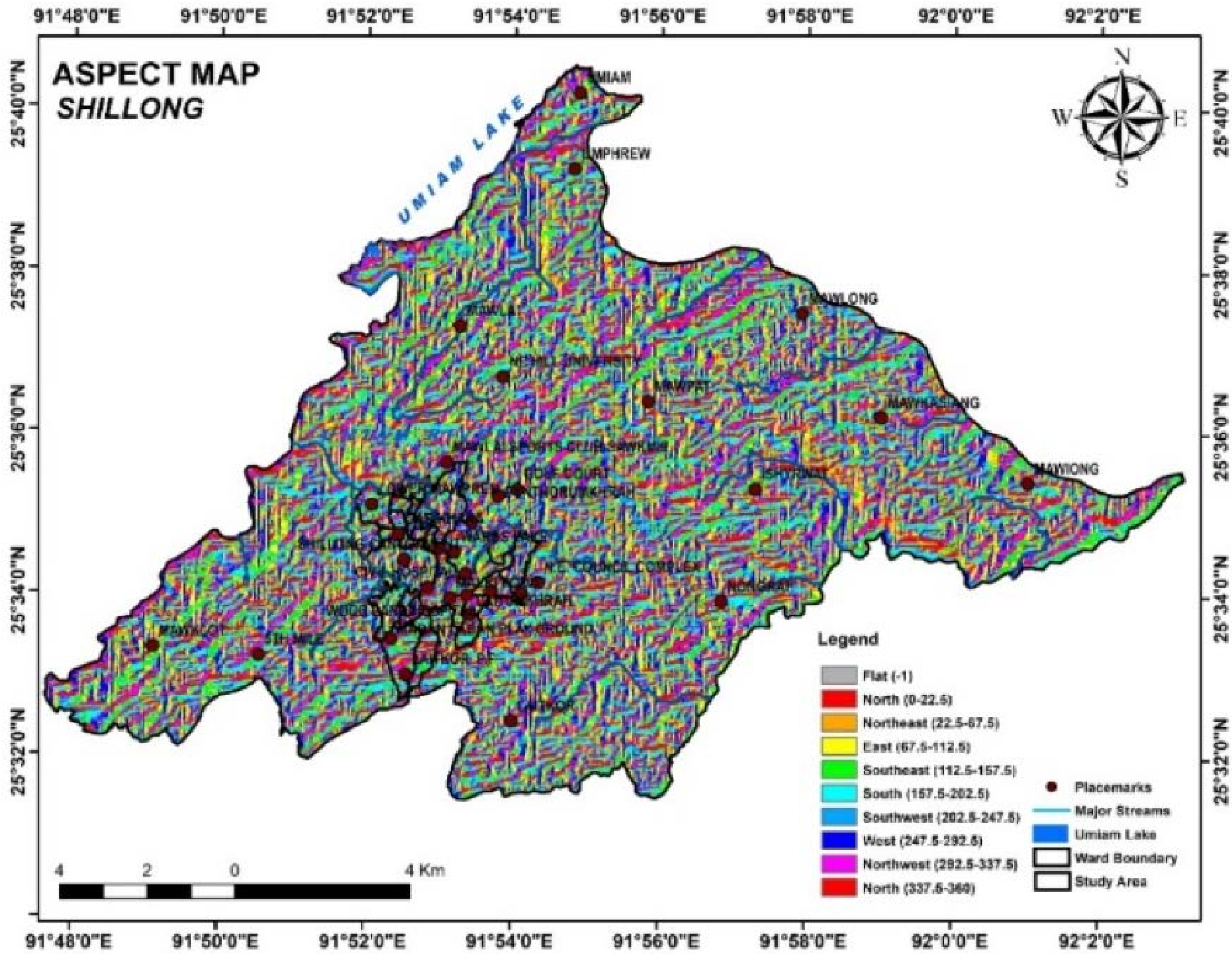


Figure 19: Aspect Map, Shillong
Source: NESAC

3.4.7 Elevation

The elevation is useful to classify the local relief and locate points of maximum and minimum heights within terrains. To calculate flood and landslide densities for different relief classes of Shillong, the relief map was divided into five altitude classes: 625-1048 m, 1048-1327 m, 1327-1621 m, 1621- 1981 m, 1981-2588 m. o calculate flood and landslide densities for different relief classes of Shillong, the relief map was divided into five altitude classes: 861-1087.25 m, 1087.25- 1239.46 m, 1239.46-1362.87 m, 1362.87 -1494.51 m, 1494.51 -1654.94 m, 1654.94.-1910 m. The Shillong agglomeration covers an elevation range from 861-1910 m.

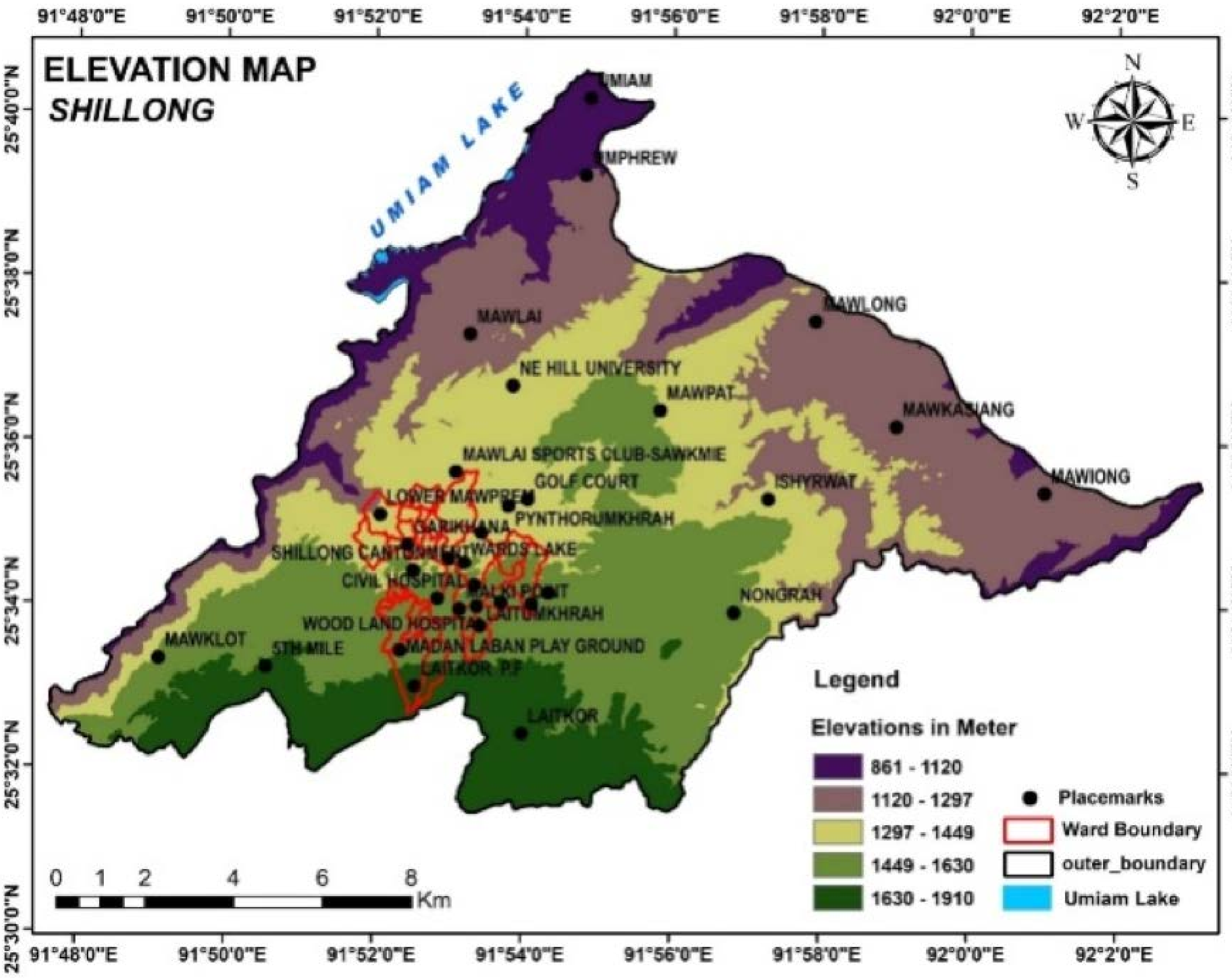


Figure 20: Elevation Map, Shillong

Source: NESAC

3.4.8 Land Use Cover

Land cover acts as a shelter and reduces the susceptibility of soil erosion, landslides and the get water on the action of the precipitation. Several researchers (Reis S, Yomralioglu T, 2006) (Yalcin A, 2008) have emphasized the importance of land cover on slope stabilities.

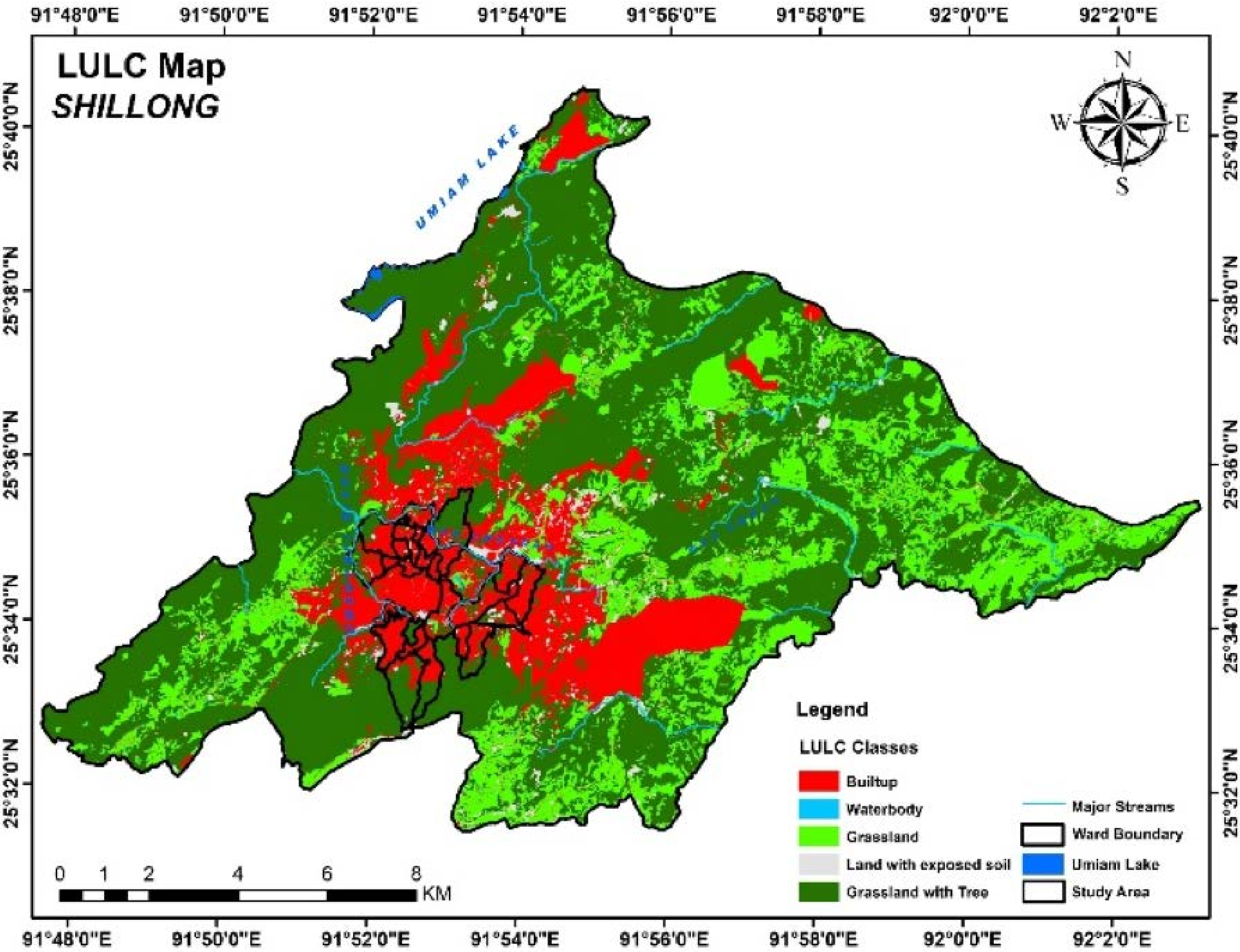


Figure 21: Land use Land cover Map, Shillong

Source: NESAC

3.4.9 Soil Stability

Soil texture and depth influence slope stability. On a micro-scale, the rate of water movement in hillslope soils is best characterized by hydraulic conductivity. Clayey soils and compact silty soils with very small interstitial pores have much lower hydraulic conductivity values than coarse-textured soils. The hydraulic conductivity of a confining layer underlying unstable landforms regulates long-term drainage and thus controls the moisture content of the overlying soil mantle (Sidle et al., 1985). When a permeable layer is confined within a clayey matrix, pore pressures can accumulate, leading to slope failure. Additionally, highly porous moderately deep soils on very steep slopes may become unstable after extended periods of rainfall even if positive pore pressures do not develop (Sidle and Ochiai, 2006). The soil map was prepared from the following work of the Shillong HRVA report.

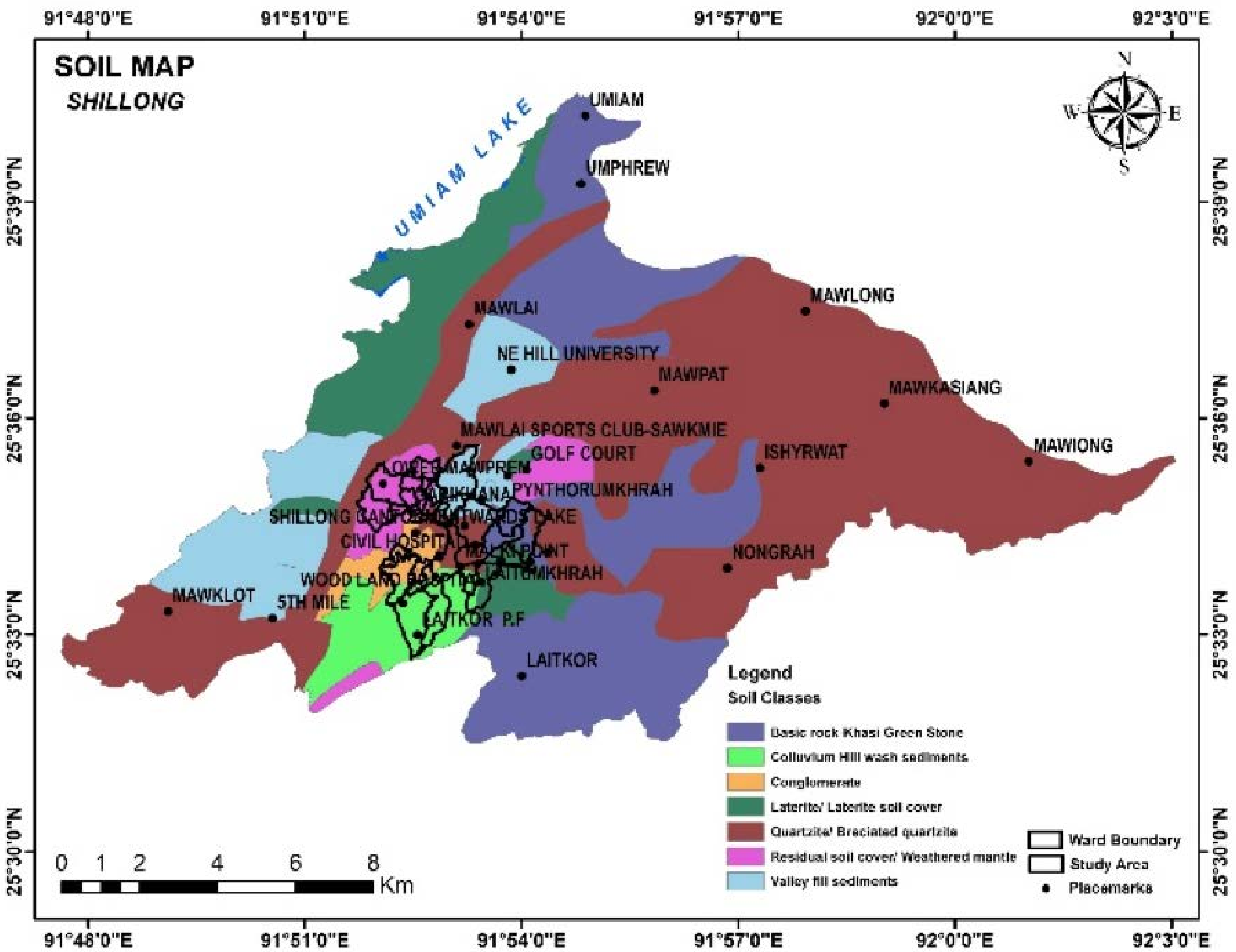


Figure 22: Soil Stability Map, Shillong
Source: NESAC

3.4.10 Geology

Lithology is one of the most important parameters in multi-hazard studies because different lithological units have different susceptibility degrees (Dai FC, Lee CF, Li J, Xu ZW, 2001); (Yesilnacar and Topal, 2005); (Yalcin and Bulut, 2007); (Nefeslioglu et al., 2008). The landslide event, a component of the geomorphological research, is related to the lithological characteristics of the land. It is extensively accepted that lithology significantly influences the occurrence of landslides because lithological variations often lead to a difference in the strength and permeability of soils and rocks. Shillong consists of low-grade metamorphic rocks of Shillong group comprising quartzites with sub-ordinate phyllite of high foliation and slates and conglomerate. The rocks are highly weathered with soil cover ranging in thickness from less than 1 m to about 10 m at places. The landslides along NH-40 are confined to the Shillong group of rocks and are more frequent where development activities have altered the slope profile. Incidentally, all the active landslides during the monsoon period are encountered along NH-40, in the stretch characterized by well-bedded and jointed phyllite. The type of slide was mostly debris fall. Within the city, there are no major landslides.

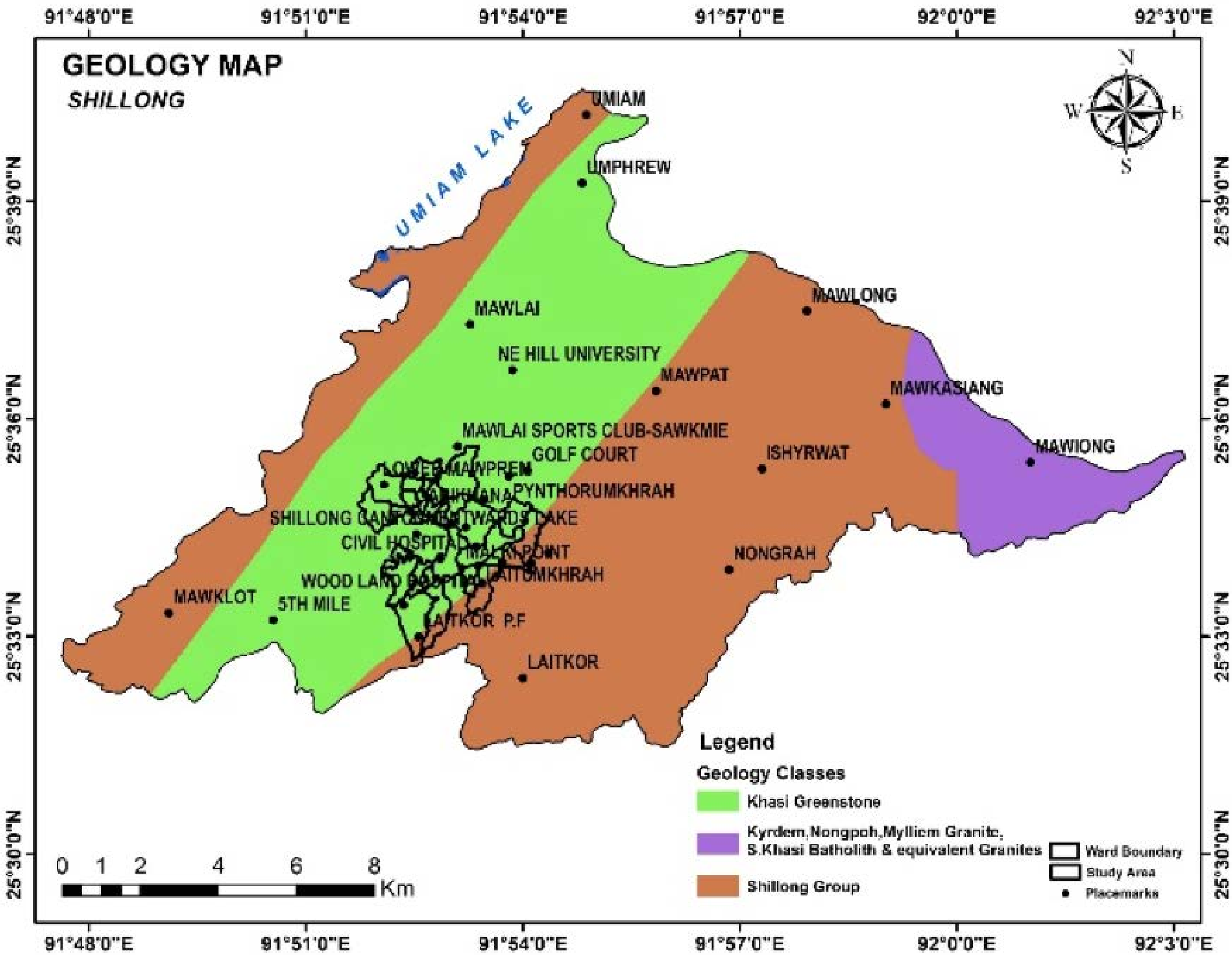


Figure 23: Geology Map, Shillong
Source: NESAC

3.4.11 Landslide Inventory Buffer

Landslide inventory is essential and basic information for any landslide zoning, such as susceptibility, risk, and hazard zoning. As a rule, the steeper the slope, the higher is the risk of landslide due to the higher gravity-induced shear. This is because as the slope angle increases, shear stress in soil or other unconsolidated materials generally increases, which leads to sliding. The inventory data includes the information related to locations, classification, volume, travel distance, state of activity and date of occurrence of land sliding in an area. There are different methods to identify landslides. Total 90 landslide inventory has been identified within Shillong, mostly consist of the NH-40. Multiple buffer tools in Arc. GIS 10.3 was used to prepare an inventory buffer map on an interval of 100 m covering ten classes 0-100 m, 100-200 m, 200-300 m, 300-400 m, 400-500 m, 500-600 m, 600-1000 m, 1000-2000 m, 2000 m-3000 m, >3000 m distance.

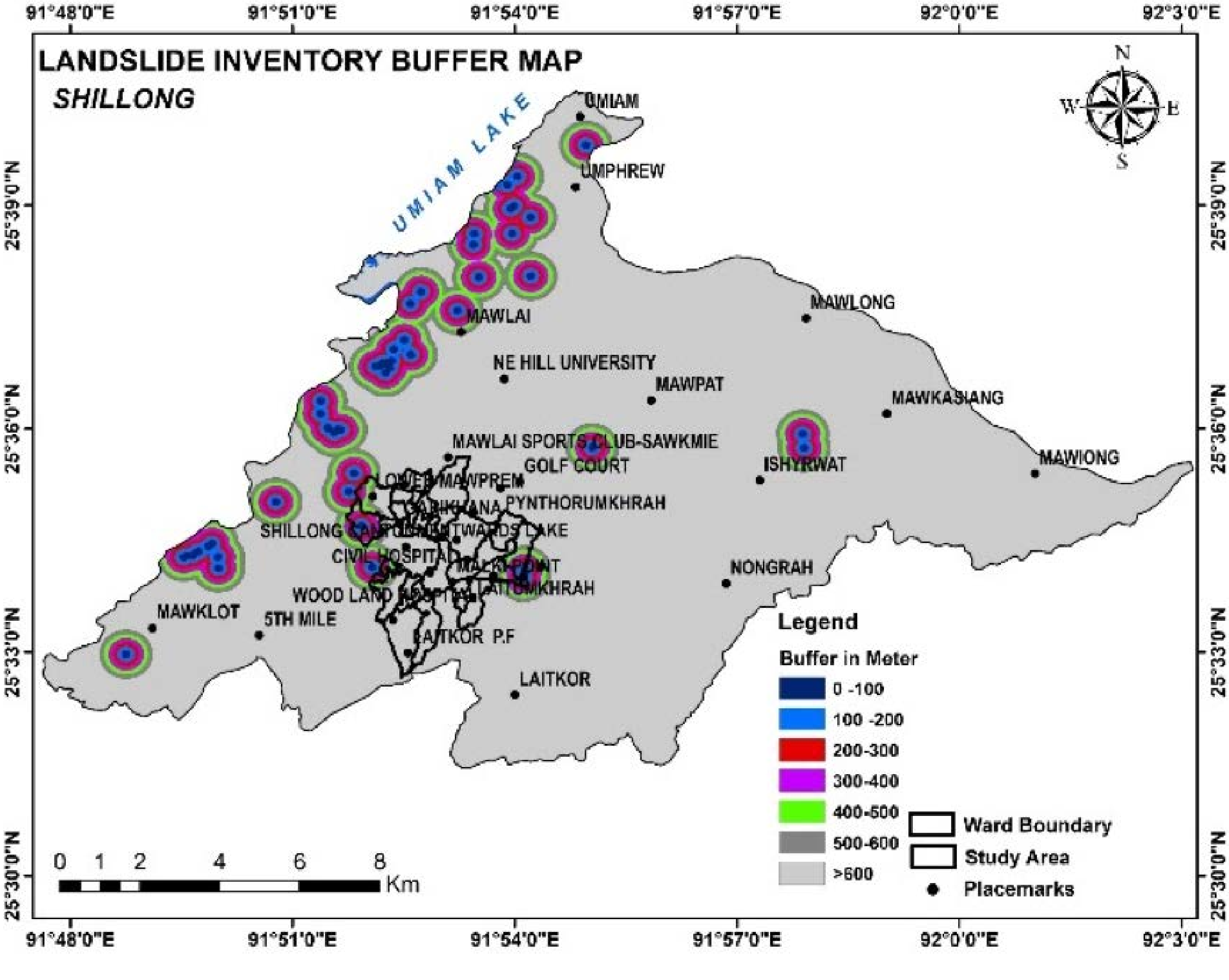


Figure 24: Landslide Inventory Buffer Map, Shillong

Source: NESAC

The city experiences most landslides during the monsoon that causes damages to houses, roads, and sometimes agricultural land. However, the potential of earthquake-triggered landslides cannot be ruled out, as the region has a potential for very strong earthquakes. To get the final landslide susceptibility zone for Shillong agglomeration, seven factors, namely Slope, LULC, Aspect, Elevation, Inventory, Geology, and Soil, have been given the rank of each class layers based on susceptibility to landslides. Weights to each factor have been assigned based on importance and the analytical hierarchy approach. Here Slope has been given the highest weight, and the aspect was the lowest. The result of the LSI map derived from the equation (1) in Arc.GIS 10.3 software. LSI contains numerical susceptibility information where the highest value indicates high susceptibility and the lower value indicates low susceptibility. LSI value was then divided into five susceptible zones, including "Very Low", "Low", "Medium", "High", and "Very High".

Rating method	Normal Weight
Slope	0.22
LULC	0.1
Aspect	0.08
Soil Stability	0.16
Elevation	0.15
Geology	0.12
Landslide Inventory Buffer	0.17
Sum	**1**

Table 12: Landslide Susceptibility weightage

Hazard Classes	Ward	Number
Very High	Nil	Nil
High	1,4,20,21	4
Medium	2, 3,5 ,6, 7,8, 9,10,11,12,13,14, 15, 16, 17,18,19,22,23,25,26,27	22
Low	24	1
Very Low	Nil	Nil

Table 13: Ward wise Landslide vulnerability

Hence we find that wards 1,4,20,21and 6 have a higher susceptibility to landslides, whereas ward 24 has low susceptibility. This indicates that nearly four wards are categorised as Highly Vulnerable and 22 wards as medium, whereas one ward is categorized under low vulnerability.

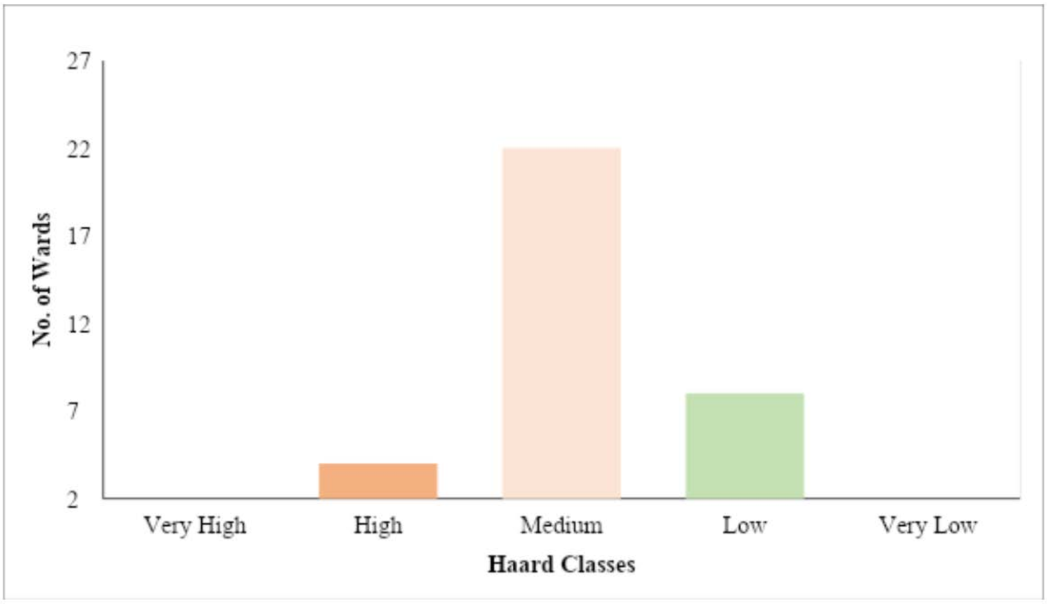


Figure 25: Ward level Landslide Vulnerability

The result determines that the area along the National Highway 40 and near the Umshyrpi River consists of very high susceptibility. In case of municipal wards of 20, 21, 27 and 26 falls under high and medium susceptibility.

Based on the result of the obtained susceptible map of Shillong, 42.14% of the total area found in low susceptibility. Whereas 0.45% of the total area found in very high susceptibility. Medium and high susceptible zones make up 49.6% and 7.81% of the total area, respectively. The result determines that the area along the National Highway and near the Umshyrpi River consists of very high susceptibility. Whereas low susceptible area incorporates the areas of Shillong Municipality and surrounding agglomeration area.

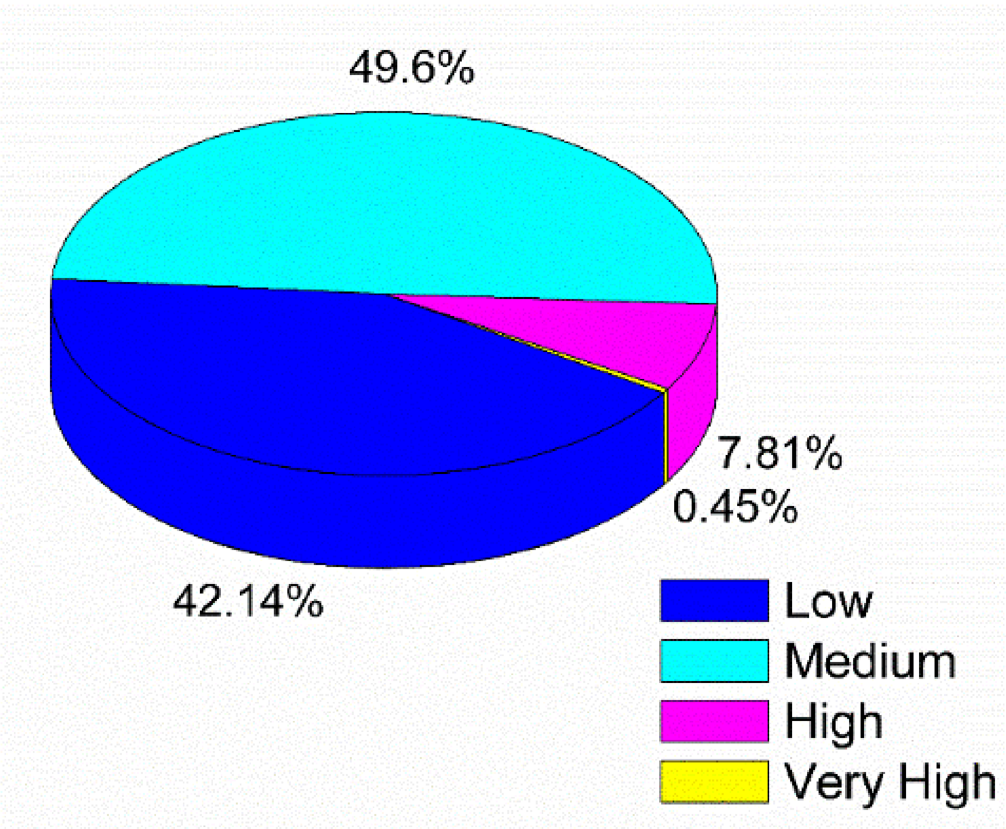


Figure 26: Landslide susceptibility % share

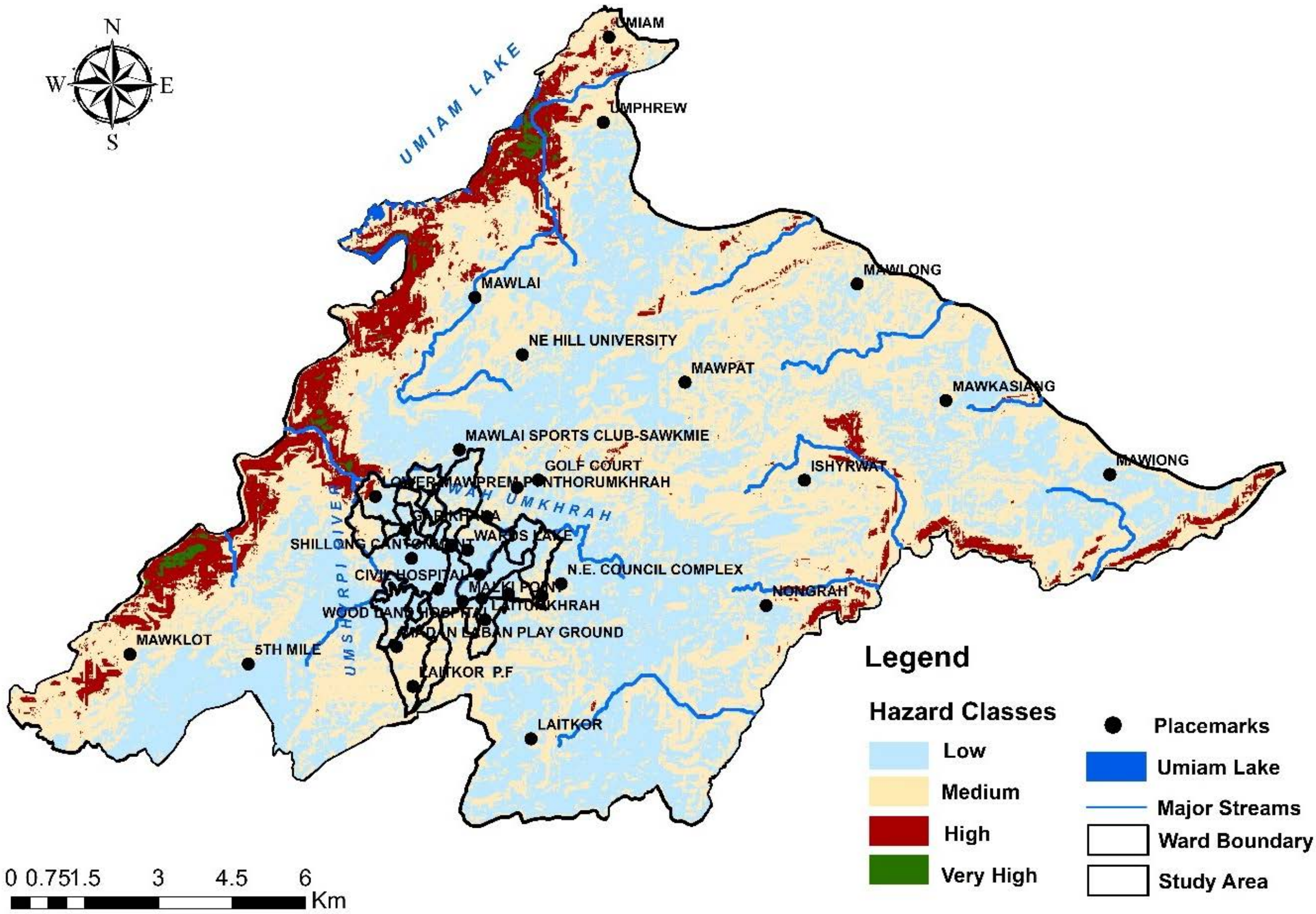


Figure 27: Landslide Susceptibility Map, Shillong

Source: NESAC

3.5 Vulnerability to Landslide

3.5.1 Major Landslide events and its impact

According to CDMP (2016), some of the localities that have experienced landslides are Laitumkhrah (2008), Arbuthnot Road, Lumparing, Jackson Trace Road, and MES Road, Sericulture farm, Mc Cabe Road, Streamside Road, Bethesda, WahKynrud Raid Laban, Nongrimbah Stream, and Um Saw Saw, Lumparing. According to GSI, there is only one natural landslide within the city, which lies on the left bank of the Umshirpi River near Lumlyer. The remaining landslides occurred due to human interference.

Figure 28: Landslide in Shillong on the GS Road (25° 39.107′ N, 91° 53.890′ E)

Image By: IRADe Team

3.5.2 Population Vulnerability

In terms of the landslide susceptible zones, we can trace the vulnerable population to landslide events. We find that almost 21% of the city population lie in the High landslide demarcated areas, 77% of the population in the Medium and 2% population in the low hazard-prone area.

Hazard Classes	Ward No	Ward Name	Total Population	%	Total
Very High	**Nil**				
High	**1**	Laitumkhrah	11537	6.17	**20.81**
	4	Laitumkhrah	2753	1.47	
	20	Mawprem	10613	5.68	
	21	Mawprem	14009	7.49	
Medium	**2**	Laitumkhrah	3266	1.75	**77.28**
	3	Laitumkhrah	5437	2.91	
	5	Malki	4908	2.62	
	6	Malki	4888	2.61	
	7	European Ward	4891	2.62	
	8	European Ward	6009	3.21	
	9	Police Bazar	2145	1.15	
	10	Jail Road	5766	3.08	
	11	Jail Road	48643	26.01	
	12	Mawkhar	2797	1.50	
	13	Mawkhar	5337	2.85	
	14	Jaiaw	3032	1.62	
	15	Jaiaw	3838	2.05	
	16	Jaiaw	4067	2.17	
	17	S.E.Mawkhar	3270	1.75	
	18	S.E.Mawkhar	3875	2.07	
	19	Mawprem	4556	2.44	
	22	Kench's Trace	2973	1.59	
	23	Kench's Trace	8161	4.36	
	25	Laban	5218	2.79	
	26	Lumparing	6319	3.38	
	27	Lumparing	5133	2.74	
Low	**24**	Laban	3568	1.91	**1.91**
Very Low		Nil			
Total Population			**187009**		
Source: Census Abstract, 2011					

Table 14: Household and Total Population Vulnerability

Chapter 4

Hazard Risk Assessment Urban Floods

4.1 Introduction

4.1.1 Definition

Urban floods are the result of inadequate or poor maintenance of stormwater drains, improper planning, encroachment on drains and water bodies, occupation of low-lying areas, modification of catchments, and climate Change.

Urban flooding is caused due to inadequate or inappropriate drainage. High-intensity rainfall can cause flooding when the city sewage system and draining canals do not have the necessary capacity.

Flash flood is caused by heavy or excessive rainfall in a short period of time, generally less than 6 hours. They can occur within minutes or a few hours of excessive rainfall, landslides and failure in dam or levees.

Flash floods are short-term events, occurring within 6 hours of the causative event (heavy rainfall, dam break, levee failure and rapid snowmelt) and often within 2 hours of the start of high-intensity rainfall. A flash flood is characterized by a rapid stream rise with depths of water that can reach well above the banks of the river, carrying with it large amounts of debris and causing high damage due to its suddenness (SSDMA, 2019).

Flash floods are one of the most common forms of natural disaster in the Himalayan region. They consist of a sudden and very strong surge of water, usually along a riverbed or dry gully, that can carry rocks, soil, and other debris. Although flash floods generally affect smaller areas and populations than riverine floods, their unexpected and intense nature means that they pose a significant risk to people and infrastructure, leading to death and destruction.

4.1.2 Flood classification

Urban floods can be classified as floods due to:

- Local heavy rainfall
- River overbank flow
- High tides or storm surges

Insufficient or poor drainages cause floods due to locally heavy rainfall. Floods due to river overbank flow occur when the river level rises above river banks. Excessive river levels are normally caused by high runoff from upstream and the backwater effect of high tides at the river mouth. Construction of cities in floodplains reduces storage and block floodway in the flood plains causing flood damage even worse. Flood dikes in cities may be breached due to high flood levels and cause severe flood damages. Cities in coastal areas are normally located in low lying areas where drainage is difficult without pumping. High tides or storm surges can hamper flood drainage to the sea and cause prolonged flooding with polluted floodwater and health problems in cities. Effects of climate change increase more heavy rainfall, severe and frequent flooding, which are more difficult to predict (NRDC, 2019).

4.2 Floods in India

There has been an increasing trend of urban flood disasters in India over the past several years, whereby major cities in India have been severely affected. The most notable amongst them are Hyderabad in 2000, Ahmedabad in 2001, Delhi in 2002 and 2003, Chennai in 2004, Mumbai in 2005, Surat in 2006, Kolkata in 2007, Jamshedpur in 2008, Delhi in 2009 and Guwahati and Delhi in 2010 (NDMA, 2018).

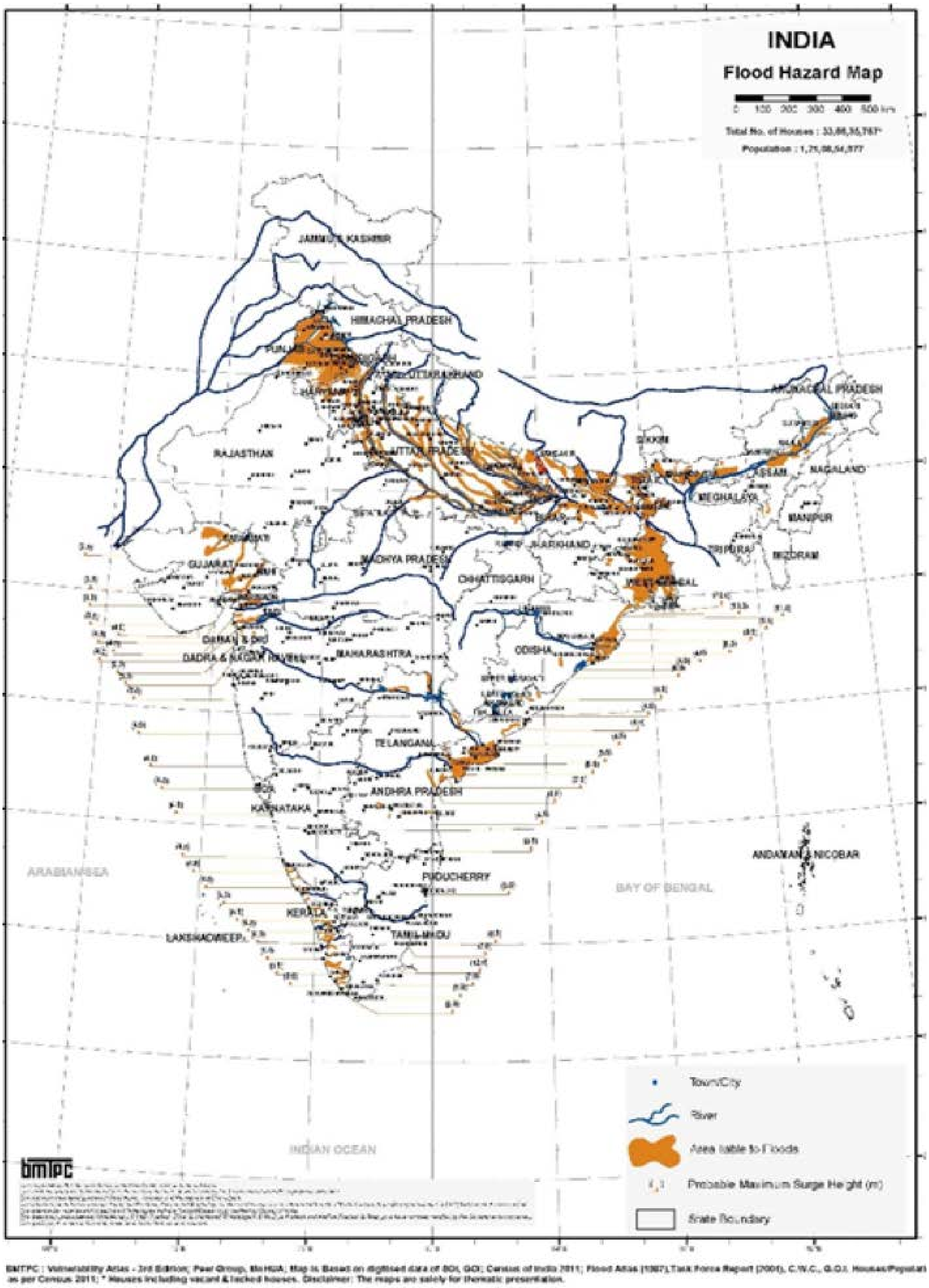


Figure 29:Landslide Incidence Map, BMTPC, MHUA &NIDM, 2019

4.2.1 Floods in Meghalaya

The State with hilly terrain does not suffer from floods; however, flash floods may be caused due to heavy rain, resulting in river bank erosion and some local damage. In Meghalaya, floods occur in river valleys when the flow exceeds the capacity of the river channel, particularly at bends or meanders. The plain areas of Meghalaya adjoining Assam are affected by floods due to the backflow of water from the River Brahmaputra during the flood season between June and October. The tributaries like Krishnai, Jinari, Jingjiram, Rongai, Dudhnoi, Ringgit, Gohai, Dilni cause flood in the plain areas of the State. (MSDMA, 2016).

4.3 Floods in Shillong city

The city witnesses flash floods during the monsoon season due to high-intensity rainfall for prolonged hours. Other important factors responsible for flooding in the city are the clogging of drains and insufficient capacity of the rivers flowing through the city area (CITY DISASTER MANAGEMENT PLAN, 2018). Polo and Pynthorbah areas in the city are prone to flooding in monsoon, as they are low-lying areas, and the WahUmkhrah River, which flows through these areas, overflows its banks with almost every heavy downpour. The number of flooded streets has been rising over the years during the monsoon season in some city patches due to improper and uncontrolled construction. Almost 25% of waterlogging (Mott MacDonald, 2017) incidences have been recorded in the city. According to the Shillong CDMP (2016), the following areas have drainage congestions causing flash floods:

- WahUmkhrah Mc Cabe Road
- Polo Market
- Don Bosco Road
- NH 40 WeikingPdengshnong
- Budha Mandir Road
- Veronica Road
- Dhankheti Junction

4.3.1 Causes of Floods

Shillong witnesses flash flood during the monsoon season due to high-intensity rainfall for prolonged hours. Other important factors responsible for flooding in the city are the clogging of drains and insufficient capacity of the rivers flowing through the city area. Due to heavy downpours during the monsoon season, the water tops the banks along most of the streams causing flooding in localities in the vicinity of these streams. This is aggravated by a drastic reduction in channel capacities in most streams due to encroachments along their banks by buildings.

The city is drained mainly by the upstream reaches of WahUmiam, WahUmkhen, and WahTamdong Rivers. Most of the drainage lines in the area are first, second, and third-order reaches of these rivers. The Polo area of the city is most affected by the flash flood. This is due to the clogging of WahUmkhrah and the decreasing width of the river due to human activities. The other affected localities are Pynthorbah, Golflink, Lumshyiap, Langkyrding, Nongmynsong, MawlaiPhudmuri, MawlaiNongpdeng.

Encroachment and clogging of the channels are the major causes of flooding. The building of settlements in the floodplain has choked the river's natural flow, thus causing waterlogging and submergence in low-lying areas. The famous Polo ground area, Pynthorbah, Langkyrding, and the lower part of Nongmynsong are developed on the floodplain. The water from nearby steep terrains is accumulated in the floodplain, which causes waterlogging in the area.

It has also been observed that drains are not in good shape at many places along the roadside. At several places, rainwater flows onto the roads, and many of the roads are without any drains. Dumping garbage and waste materials at unauthorized sites and on roads clog the drains, which subsequently cause waterlogging and increasing the flooding problem (CITY DISASTER MANAGEMENT PLAN, 2018).

Some of the low-lying areas in the city are waterlogged during the monsoon, largely due to clogging and decreasing the width of the river due to human activities. The areas of the city, which lie close to the river WahUmkhrah (northern parts of Ward 10, 8, 2; eastern and northern parts of Ward 1 and 139 southern part of ward 4) and Umshyrpi (northern parts of Ward 10, 8, 2; eastern and northern parts of Ward 5, 6, 22, 23, 24, 25 & 26 and southern part of ward 3 & 7) get flooded during the monsoon season. As a result, many properties and agricultural lands are damaged (CITY DISASTER MANAGEMENT PLAN, 2018).

4.4 Floods Susceptible Zonation

4.4.1 Introduction

As stated by (Dobler et al., 2012), flood susceptibility is a prerequisite for sustainable flood risk management, as it provides useful information about the appropriate strategies for adaptation and mitigation.

4.4.2 Existing Flash flood Vulnerability Assessment

Multi-Hazard Risk and Vulnerability Assessment Report and risk atlas of Shillong City (Meghalaya) were carried out as part of the ongoing GOI-UNDP Disaster Risk Reduction (DRR) Programme to strengthen the institutional structure to undertake disaster risk reduction activities at various levels and to develop preparedness for recovery. The report provides findings of hazard mapping and analysis of key natural hazards the city is exposed to, namely– earthquake, flood, landslide, thunderstorm (associated with strong wind, lightning, hailstorms and cloudbursts), cold wave, heat-wave, fire, and climate change impact on hydro-meteorological hazards.

The city has been divided into smaller watershed units contributing to the drains of the city. Then return period (design) discharges for each sub-watersheds have been carried out. For analyzing the rainfall climatology and return period (design) rainfall of the city region, the IMD rainfall station at Shillong has been considered. The design rainfall at Shillong station has been adopted from the Brahmaputra Basin PMP Atlas developed by the Central Water Commission (CWC, 2014) using data from 1957-2010. Then The rainfall intensity corresponding to the time of concentration duration has been used. Using this design rainfall intensity for a selected duration, the flows have been estimated using the rational formula for all the sub-watersheds in the city.

Flood hazard associated loss assessment was carried out for various flood events at different return period scenarios (2, 5, 10, 25, 50, and 100 years) and six climate change scenarios (two each for 25, 50, and 100) and risk assessment have been considered (RMSI, 2019).
The mapping methodology has not been clearly stated in the document.

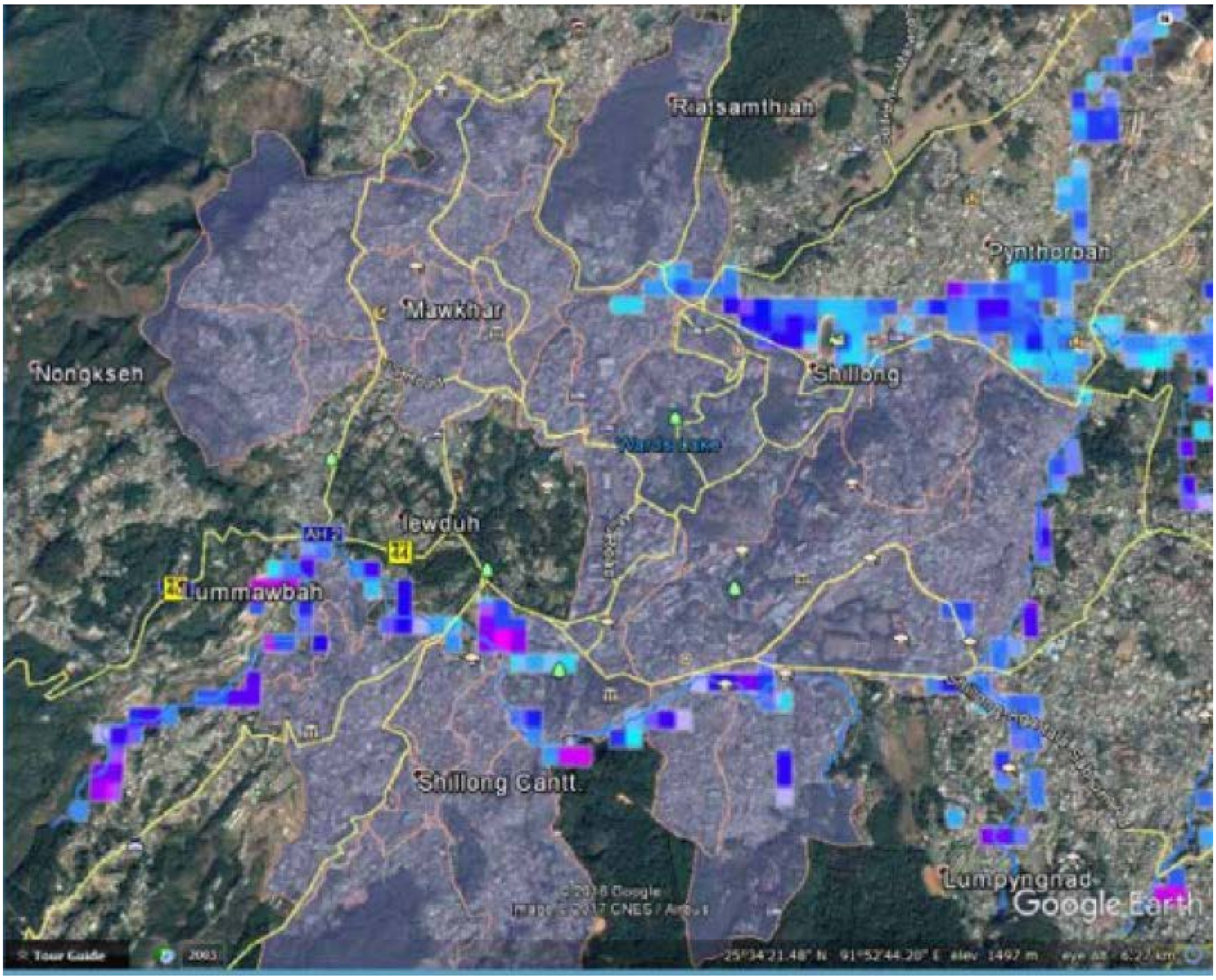


Figure 30: 100-year return period flood hazard map overlaid on Google Earth(Multi-Hazard Risk and Vulnerability Assessment Report and risk atlas of Shillong City (Meghalaya))

4.4.3 Current Study

To map the flood susceptible zones, slope maps, elevation maps, and Drainage density maps were developed on a scale of 1: 4000, and the maps are overlaid. Weightage has been given to each aspect to procure highly susceptible areas and those having very low susceptibility to floods.

GIS-based Multi-criteria Decesion Analysis (MCDA) technique used to develop cadastral maps for the scale of 1:4000 and map the hazard/disaster wise vulnerable zones of the Shillong Municipal Area.

4.4.4 Methodology

There are a good number of multi-criteria based hazard zonation techniques presently being used worldwide. This project attempts to demonstrate the applicability and strength of GIS-based Analytical Hierarchy Process (AHP) with criteria such as Land-use/ Land cover, slope, Aspect, Elevation, Landslide Inventory buffer, Lineaments buffer, Lithology/Geology, Soil Stability, Drainage Density, Isoseismal, Structural buffer, Soil, Building Density and Geomorphology for generation of high-resolution Multi-Hazard susceptibility maps for Shillong Agglomeration.

The **Analytical Hierarchy Process (AHP)** is a problem-solving system and a methodological technique for representing the aspects of each problem (Saaty and Vargas, 1991). There are different types of AHP methods. Amongst them, the Rating methods have been chosen for this project. The rating method requires the decision-maker to estimate weight based on a predetermined scale; e.g. 0 to 100 can be used (Easton, 1973). In this method, a score of the highest rate is assigned to the most important criteria. For the Susceptibility map, it is necessary to give some score to each of the criteria or layer as per their suitability. A matrix of calculation has been done to normalize the weight. While normalizing the weight, it should be careful that the sum of the normalized weight comes as 1. In this method, all the raster criteria were reclassified and converted to vector layers. The class weight has been given to each class of individual vector layers according to their importance. The final susceptibility map was prepared by the following formula:

Urban Floods Susceptibility Map= ∑ [Criteria map * Weight]

For Mapping of Flood susceptibility, three criteria were selected. These principal criteria are Slope, Elevation and Drainage Density.

Ranking of all criteria has been done based on their susceptibility to the landslide. Here rank 10 indicates the maximum susceptibility, while rank 1 indicates the minimum susceptibility. All the layer rank and class weight have been given based on the Bureau of Indian Standard (BIS) format, reviewing different literature of the particular area and taking experts' choice for each criterion of the different susceptibility. To get the final susceptibility zone for two cities, different layers have been used and given the rank of each class of the layers based on susceptibility to different hazards. Weight to each factor has been assigned based on importance and the analytical hierarchy approach.

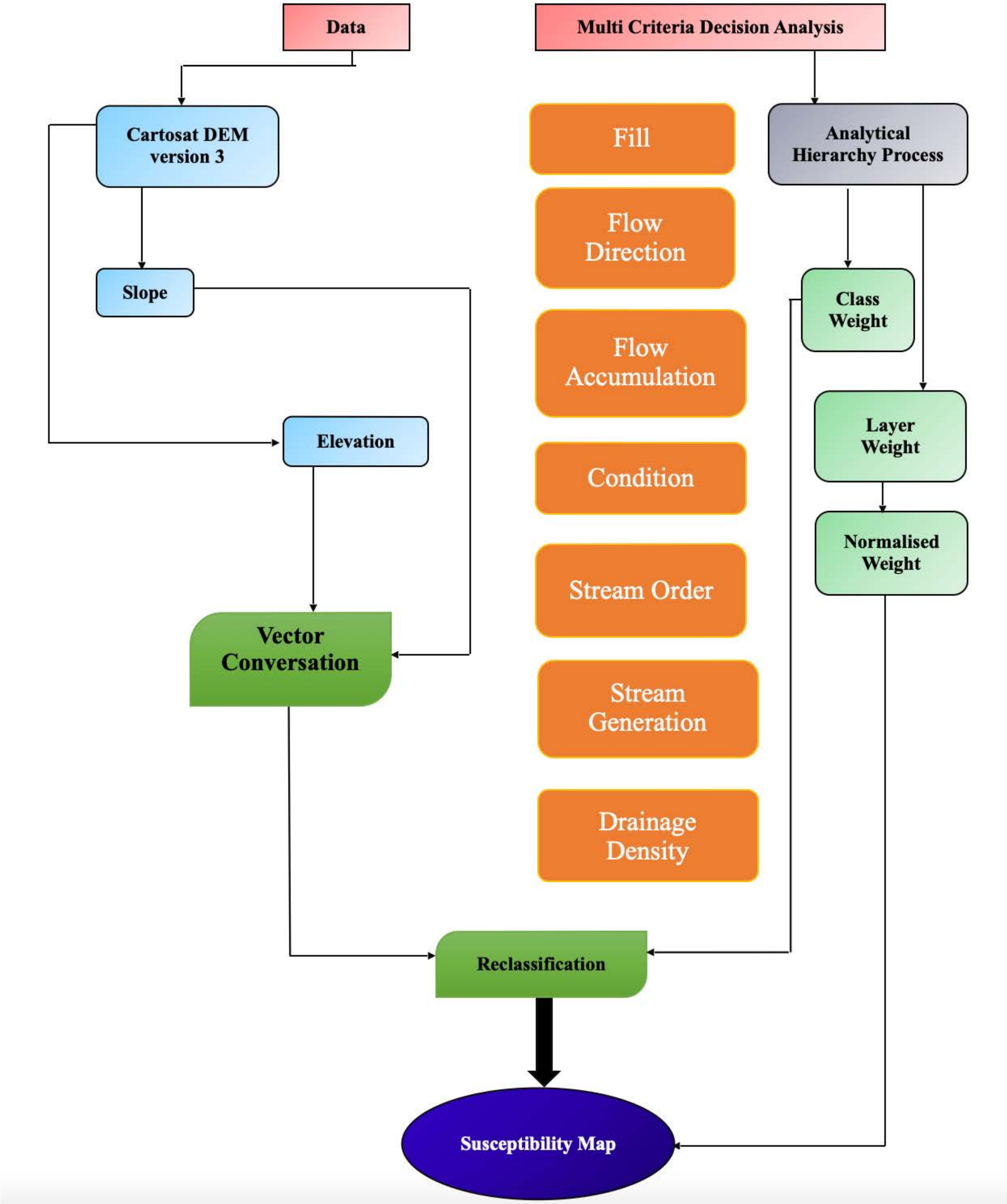


Figure 31: Hazard Susceptibility Mapping Methodology, NESAC

4.4.5 Slope

The slope is one of the main parameters in slope stability analysis. (Lee and Min, 2001) (Cevik and Topal, 2003) (Yalcin, 2008). The slope angle directly affects landslides; thus, it is used in preparing landslide susceptibility maps. In some recent studies, this parameter has been considered the most important factor in landslide susceptibility mapping. The slope map was prepared using Cartosat version 3 DEM in Arc GIS 10.3 software. For preparing a multi-hazard map of Shillong, the slope map was divided into five slope categories: very low (0-7o), low (7.1 o -14 o), medium (14.1 o -21 o), high (21.1 o -35 o) and very high (>35 o). The highest slope of the study area is 81°.

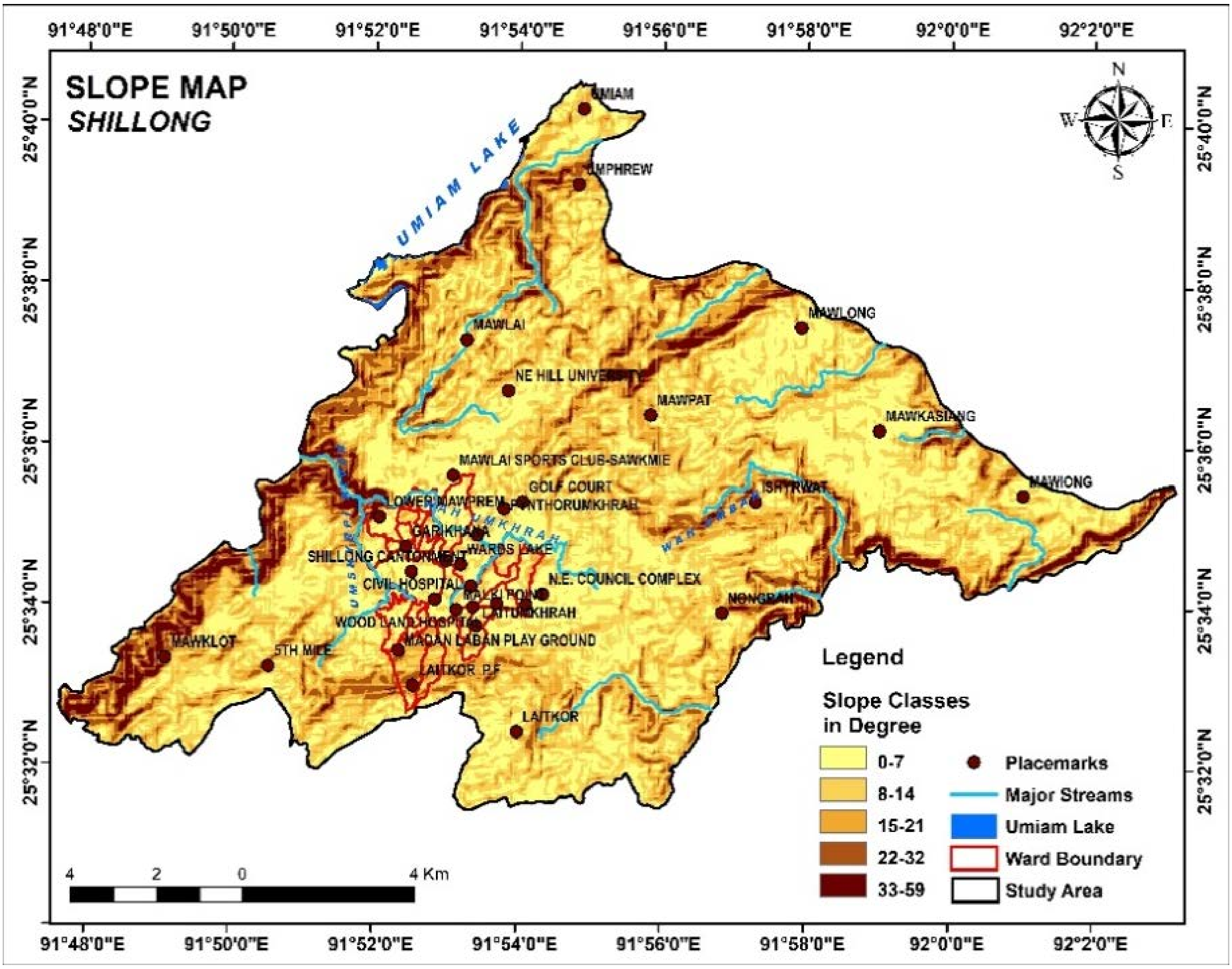


Figure 32: Slope Map, Shillong

Source: NESAC

4.4.6 Elevation

The elevation is useful to classify the local relief and locate points of maximum and minimum heights within terrains. To calculate flood and landslide densities for different relief classes of Shillong, the relief map was divided into five altitude classes: 625-1048 m, 1048-1327 m, 1327-1621 m, 1621- 1981 m, 1981-2588 m. o calculate flood and landslide densities for different relief classes of Shillong, the relief map was divided into five altitude classes: 861-1087.25 m, 1087.25- 1239.46 m, 1239.46-1362.87 m, 1362.87 -1494.51 m, 1494.51 -1654.94 m, 1654.94.-1910 m. The Shillong agglomeration covers an elevation range from 861-1910 m.

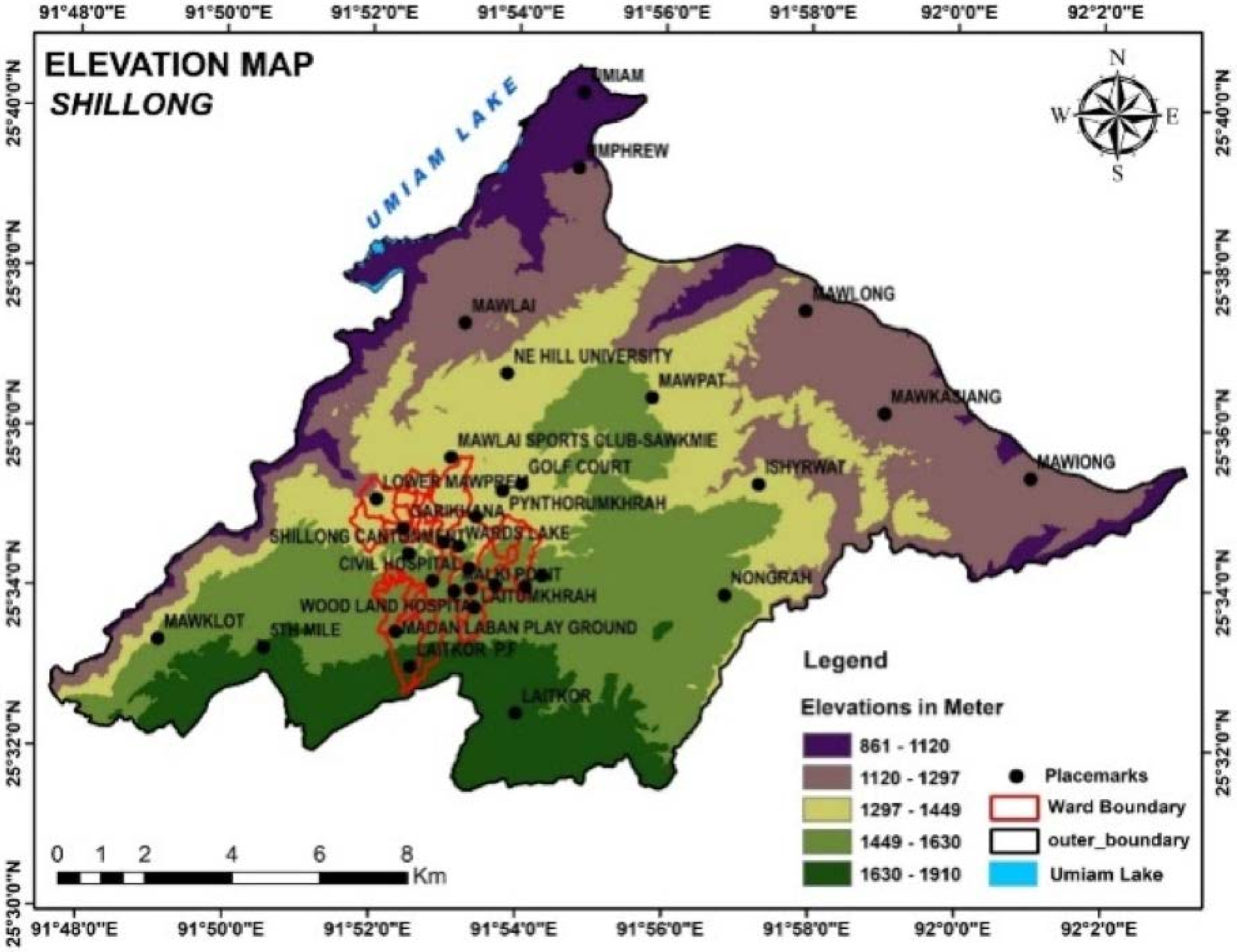


Figure 33: Elevation Map, Shillong

Source: NESAC

4.4.7 Drainage Density

A higher probability of flooding is strongly associated with higher drainage density as it indicates greater surface runoff. The drainage density map Shillong agglomeration area is computed from the drainage network map using line density command in ArcGIS. Higher surface runoff is generated in the regions with a higher drainage density than those with low drainage density. Thus, the expansion of flood risk may depend on the drainage density, which is a critical factor for flood susceptibility. It has been observed that drains are not in good shape at many places along the roadside of Shillong. At several places, rainwater flows onto the roads, and many of the roads are without any drains. Dumping of garbage and waste materials at unauthorized sites and on roads clog the drains, which subsequently cause water logging and increasing the flooding problem.

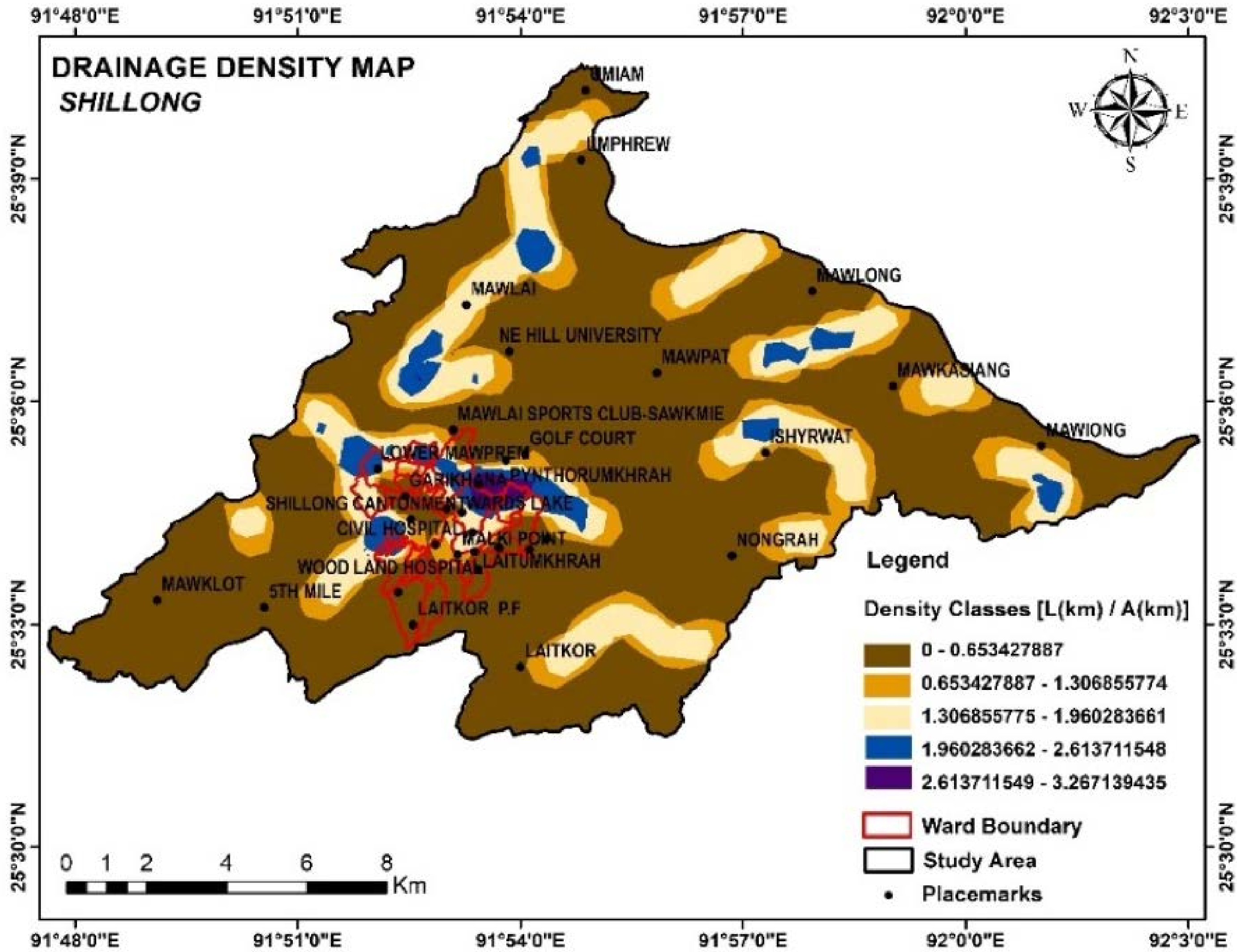


Figure 34: Drainage Density Map, Shillong

Source: NESAC

Shillong is likely to be more vigorous and widespread, with heavy downpours in a short duration. This will result in a higher probability of flash floods in terrains with steep slopes in Shillong and the entire East Khasi Hills district in a warmer atmosphere. The city witnesses flash floods during the monsoon season due to high-intensity rainfall for prolonged hours. This causes water to overflow the banks in most of the streams causing flooding in localities in the vicinity of these streams. The city drains are not in good shape at many places along the roadside. At several places, rainwater flows along the roads, and many of the roads are without any drains. Floods and waterlogging in the city's low-lying areas have also become common due to the unplanned growth of the city. The southwest monsoon contributes a considerable portion of heavy rainfall in both onset and withdrawal phases, which generally lead to flash floods in a short time. The low lying areas of Shillong are likely to be more vigorous and widespread, with heavy downpours in a short duration. This will result in a higher probability of flash floods in terrains with steep slopes in Shillong and the entire East Khasi Hills district in a warmer atmosphere.

Using the AHP model, the flash flood was performed by giving criteria rank and layer weight. To get the flash flood susceptibility zone for Shillong agglomeration, three factors, namely Slope, Elevation and Drainage Density, have been given each class of the criteria based on susceptibility to flash flood. Here Elevation has been given the highest weight, and the slope was the lowest. The Flash Flood susceptibility map derived from the equation (1) using a raster calculator in Arc.GIS 10.3. Flash Flood susceptibility contains numerical susceptibility information where the highest value indicates high susceptibility and the lower value indicates low susceptibility. The susceptibility values were then divided into five susceptible zones, including “Very Low”, “Low”, “Medium”, “High”, and “Very High”.

S.No.	Rating method	Normalized Weight
1	Slope	0.2
2	Elevation	0.5
3	Drainage density	0.3
	Sum	**1**

Table 15: Flood Susceptibility weight age

Hazard Classes	Ward	Number
Very High	Nil	Nil
High	1,2,8,11,14, 15,20	**7**
Medium	3,6,9,10,12,13,16,21,22,23,24,25	**12**
Low	4,5,7,17,18,19,26,27	**8**
Very Low	Nil	**Nil**

Table 16: Ward wise Flood vulnerability

The assessment indicates wards 1,2,8,11,14,15,20are highly vulnerable to floods/ flash floods, whereas 3,4,5, 6,7,9,10,12,13,16,17,18,19,21,23,24,25,26,27wards have medium to low susceptibility to flood conditions.

Figure 35: Ward level flood Vulnerability

Nearly all the wards in Shillong city are vulnerable to flash floods/ urban flood situations that occur due to heavy rainfall and the overflowing of the numerous streams flowing across the city. The survey indicates that dumping waste in the water bodies has led to the decreased capacity resulting in increased risks of flash floods in the city.

It has also been observed that drains are not in good shape at many places along the roadside of Shillong. At several places, rainwater simply flows onto the roads, and many of the roads are without any drains. Dumping of garbage and waste materials at unauthorized sites and on roads clog the drains, which subsequently cause water logging and increasing the flooding problem. Based on the result of the obtained flood susceptible map of Shillong, 18.38% of the total area found in very low susceptibility. Whereas 1.01% of the total area found in very high susceptibility. Low, medium and high susceptible zones make up 55.44%, 20.5% and 4.67% of the total area, respectively. Analyses of the flood hazard maps show that encroachment and clogging of the channels are the major causes of flooding. The building of settlements in the floodplain has choked the river's natural flow, thus causing waterlogging and submergence in low-lying areas. The Polo ground and Polo market area, Pynthorbah are highly potential for a flash flood of the municipal area of Shillong. Areas of Umiam also showing very high hazards for a flash flood. The water from nearby steep terrains is accumulated in the floodplain, which causes water logging in the area.

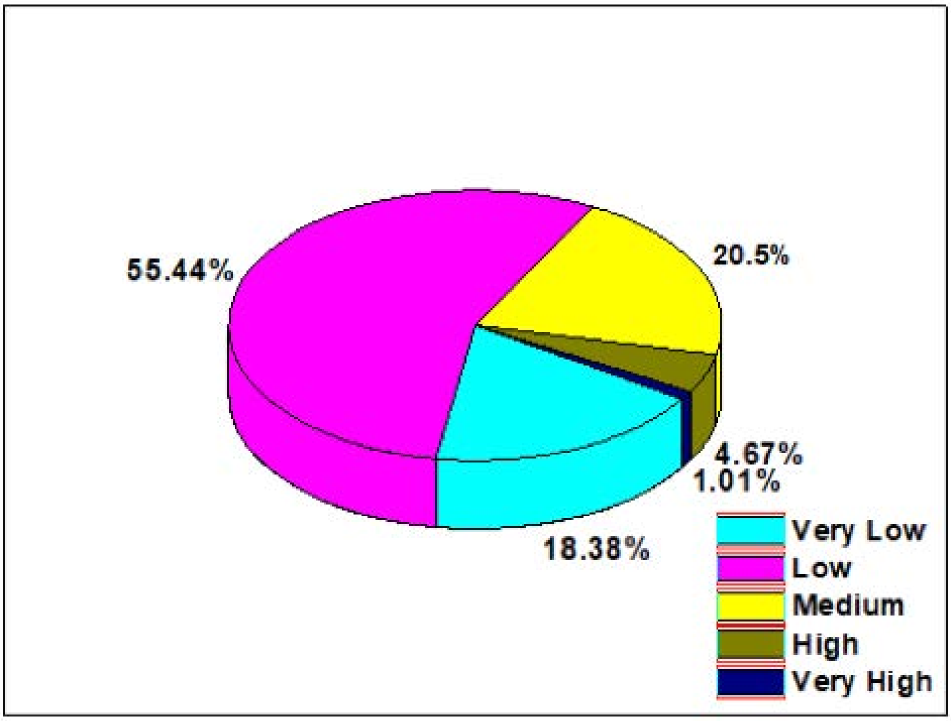


Figure 36: Floods susceptibility % Share

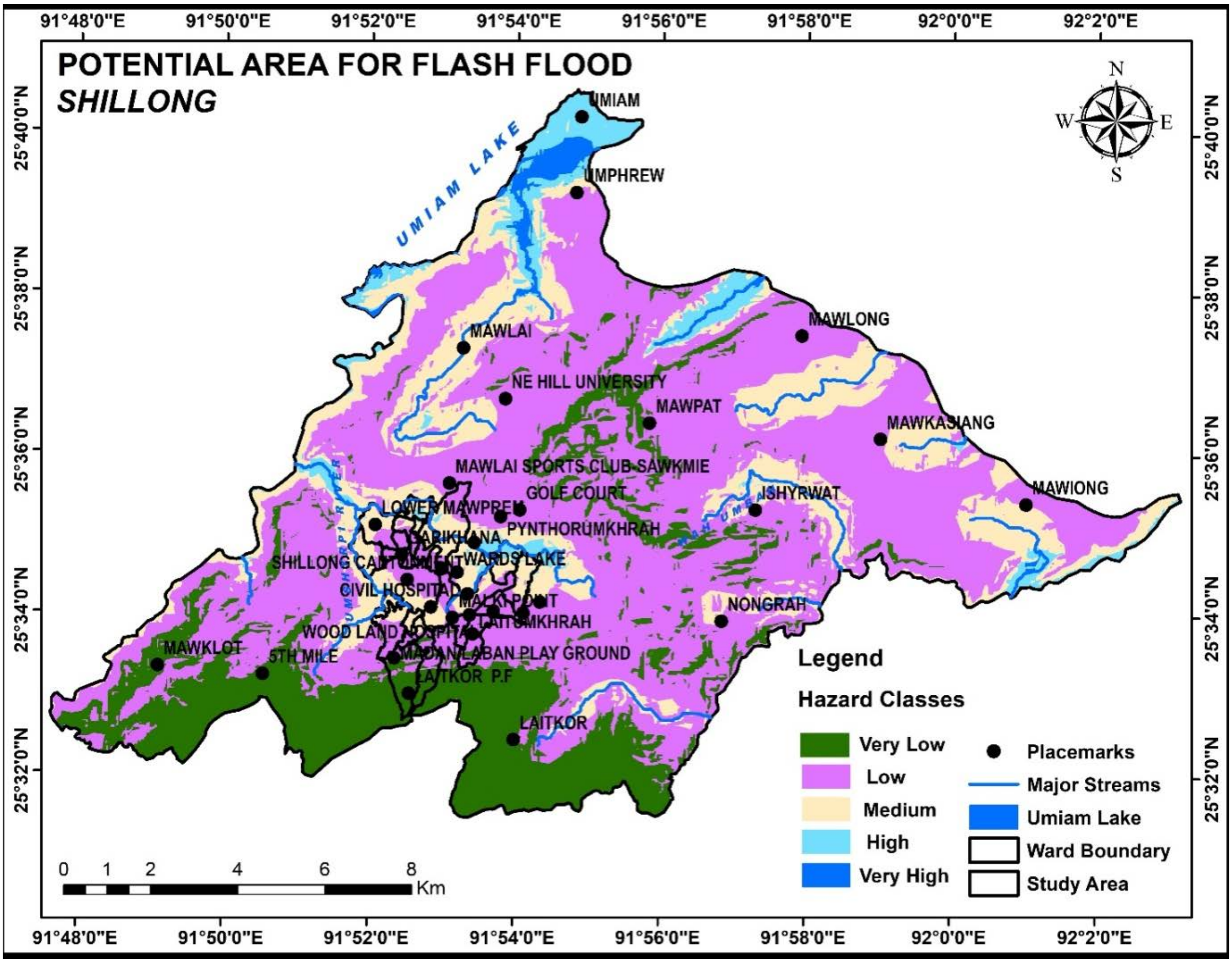


Figure 37: Flood Susceptibility Map, Shillong | Source: NESAC

4.5 Vulnerability to Floods

4.5.1 Major floods events and their impact

Shillong floods are reported every year. The Umshyrpi and the Umkhra rivers are the main rivers flowing through Shillong, merging and forming the Umiam river. The level of these rivers reaches the danger mark during heavy rainfall. Jhumm cultivation or shifting cultivation practice also increases the vulnerability to landslides in the region (NIDM, UNDP, 2018). **The following table enlists some major flood events in Shillong city:**

Year	Region	Impact	Remarks
September 2020	Meghalaya	Thirteen people died; a Flash flood and massive landslide caused traffic dislocation over Nongstoin and Mawkyrwat road and the national highway from Nongstoin to Shillong.	Heavy rainfall for five days caused flooding and landslides in Meghalaya. Mitigation was difficult due to the COVID pandemic
July 2020	Meghalaya	Five dead in Meghalaya floods, over 1.5 lakh people affected	
July 2019	Flash flood in Shillong	Incessant rain led to flash floods in the low-lying areas of the state capital and the plains belt of Garo Hills. In the city, Rainwater entered many localities in Polo and Forest Colony and submerged paddy fields in Mawlai near NEHU.	Shillong received more than 72.2 mm of rain on 9th July 2019
September 2012	Meghalaya	one lakh people were affected in Meghalaya	Brahmaputra and Jingiram rivers submerged over 100 villages

Table17: Flood Events | Source: DDMA, GSI, District Magistrate

4.6 Population Vulnerability

Regarding the population vulnerable to floods, its indicated that nearly 46% of the city's population (Shillong Municipal Board Area) lay in High susceptible area and nearly 34% of the population in medium risk areas. 19% of the population lives in low-risk areas. As per the analysis Wards1,2,8,11,14, 15,20 are highly vulnerable to flood/ flash flood event.
It is observed that though the number of wards under High Sucepitble zone are lower as compared to Medium susceptible areas, the population share in the high Suceptible zones is almost 47% of the city's population.

Hazard Classes	Ward No	Ward Name	Total Population	%	Total
Very High	Nil				
High	1	Laitumkhrah	11537	6.17	46.49
	2	Laitumkhrah	3266	1.75	
	8	European Ward	6009	3.21	
	11	Jail Road	48643	26.01	
	14	Jaiaw	3032	1.62	
	15	Jaiaw	3838	2.05	
	20	Mawprem	10613	5.68	
Medium	3	Laitumkhrah	5437	2.91	34.42
	6	Malki	4888	2.61	
	9	Police Bazar	2145	1.15	
	10	Jail Road	5766	3.08	
	12	Mawkhar	2797	1.50	
	13	Mawkhar	5337	2.85	
	16	Jaiaw	4067	2.17	
	21	Mawprem	14009	7.49	
	22	Kench's Trace	2973	1.59	
	23	Kench's Trace	8161	4.36	
	24	Laban	3568	1.91	
	25	Laban	5218	2.79	
Low	4	Laitumkhrah	2753	1.47	19.09
	5	Malki	4908	2.62	
	7	European Ward	4891	2.62	
	17	S.E.Mawkhar	3270	1.75	
	18	S.E.Mawkhar	3875	2.07	
	19	Mawprem	4556	2.44	
	26	Lumparing	6319	3.38	
	27	Lumparing	5133	2.74	
Very Low		Nil			
Total Population			187009		
Source:					

Table 18: Households and Population Vulnerability

Chapter 5

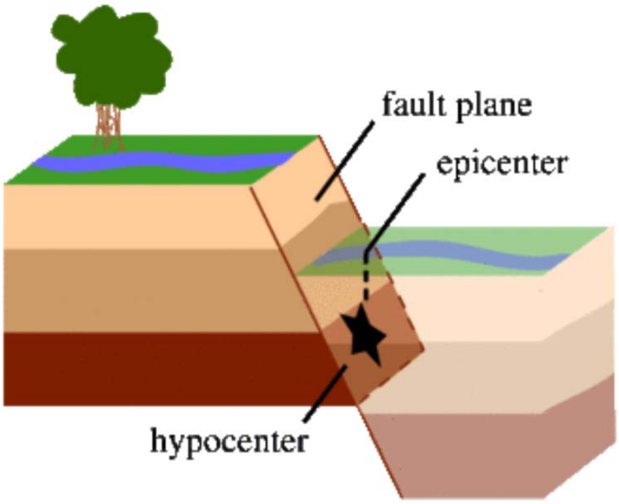
Hazard Risk Assessment Earthquake

5.1 Introduction

The Sikkim and adjoining region is known to be part of the seismically active region of the Alpine-Himalayan seismic belt, with four great earthquakes of the world of magnitude 8.0 and above occurring in this region. Earthquakes in this region are broadly associated with strain accumulation associated with the northward tectonic movement of the Indian Plate and its subsequent abrupt release (Disaster Mitigation and Management Centre, 2012). Furthermore, with the rise in population and unplanned development, the risk of such natural disasters is further aggravated in the absence of required preparedness and action plan.

5.1.1 Definition

An earthquake, a geological disaster, is a phenomenon of sudden shaking of the earth's crust due to natural causes (rock displacements, landslides, meteoritic impact etc.). Apart from the natural causes, anthropogenic factors include explosions, mining activities, and likewise (National Institute of Disaster Management , 2011).



Earthquakes are one of the most destructive of natural hazards. They can cause large scale loss of life and property and disrupt essential services such as water supply, sewerage systems, communication and power, transport, etc.

Figure 38: Earthquake Phenomenon

Source: https://www.usgs.gov/natural-hazards/earthquake-hazards/science/science-earthquakes?qt-science_center_objects=0#qt-science_center_objects

An earthquake is caused when two blocks of the earth suddenly slip past one another. The surface where they slip is called the fault or fault plane. The location below the earth's surface where the earthquake starts is called the hypocentre, and the location directly above it on the surface of the earth is called the epicentre.

https://www.usgs.gov/natural-hazards/earthquake-hazards/science/science-earthquakes?qt-science_center_objects=0#qt-science_center_objects

Source: https://www.cred.be/downloadFile.php?file=sites/default/files/Review2018.pdf

Event	2018	Average (2000-2017)
Drought	0	1,361
Earthquake	4,321	46,173
Extreme temperature	536	10,414
Flood	2,859	5,424
Landslide	282	929
Mass movement (dry)	17	20
Storm	1,593	12,722
Volcanic activity	878	31
Wildfire	247	71
Total	**10,733**	**77,144**

Source: EM-DAT (International Disaster Database)

Table 19 : Global Death Troll by Disaster Type (2018 vs. average between 2000-17)

Source: https://www.cred.be/downloadFile.php?file=sites/default/files/Review2018.pdf

In the 21st century, earthquakes and tsunamis have been the deadliest disaster (CREED, 2018).In the 2018 disaster review report by CREED, the average death toll ranging from 2000 to 2017 is highest due to earthquakes. It is 46,173, which is almost 56% of the total death toll recorded in 17 years.

Eight of the ten most populous cities on the planet are vulnerable to earthquakes. Ineffective land-use planning, inadequate enforcement of building codes and faulty construction standards put millions at risk (UNISDR). Investing in DRR helps reduce the impacts of hazards, decreases poverty and allows communities to adapt to climate change. Chile's 8.8-magnitude earthquake in 2010 killed only one person out of every 595 affected; Haiti's earthquake, while 500 times less powerful, killed one in every 15 affected (United Nation, 2018). This is due to the lack of investments made in building codes and preparedness measures.

5.1.2 Earthquake Classification

An earthquake, a geological disaster, is a phenomenon of sudden shaking of the earth's crust due to natural causes (rock displacements, landslides, meteoritic impact etc.). Apart from the natural causes, anthropogenic factors include explosions, mining activities, and likewise (National Institute of Disaster Management , 2011).

Classification of the earthquake is based on several parameters (NIDM, 2014):

- Based on the scale of magnitude (M), an earthquake may be of the Micro ($M < 3.5$) or macro ($M > 3.5$) type.
- Depending upon the extent of energy released and strength of the ground shaking, it may be of several types, like a moderate, strong, very strong, great and very great earthquake.
- Depending upon the scale of damage, the earthquake may be of various types, such as Less damaging earthquake, Moderate damaging earthquake, and catastrophic earthquake.
- Depending upon the focal depth (h) of the event, it could be a shallow earthquake ($d< 70$ km); intermediate depth earthquake ($70 < h < 300$ km); the deep earthquake ($300 < h < 700$ km).
- Depending upon the location of events in different tectonic settings, an earthquake may be an intra-plate, inter-plate, and sub-oceanic earthquake.
- Depending upon the involvement of other agents/phenomena with earthquake genesis, it may be of several types, such as Reservoir induced, Fluid-driven earthquake, Tsunamigenic earthquake, and volcanic earthquake.
- Depending upon the type of faulting involved during earthquake genesis, an earthquake may be categorized into several categories, such as normal faulting, reverse faulting, thrust faulting, and megathrust earthquake.
- Depending upon the frequency content, the earthquake may be of Low-Frequency tremors or high – Frequency tremors.
- Depending upon the epicentre distance (distance between main earthquake shock and the recording stations), the earthquake may be classified into Local, Regional and Global earthquake.

5.2 Earthquakes in India

The Indian sub-continent situated on the boundaries of two continental plates is very prone to earthquakes. Some of the most intense earthquakes of the world have occurred in India (District Collectorate, East Sichey, Gangtok, 2018-19).
Out of 35 states and union territories in the country, 27 are disaster-prone (National Disaster Management Authority). Considering the recorded history of earthquakes in the country, seismologists have classified **59% of the landmass of India** is prone to earthquakes of different magnitudes -11% in very high-risk zone V, 18% in high-risk zone IV and 30% moderate risk zone III(NIDM, 2018). The north-eastern region of the country and the entire Himalayan belt are susceptible to great earthquakes of magnitude more than 8.0. The main cause of earthquakes in these regions is due to the movement of the Indian plate towards the Eurasian plate at the rate of about **50 mm per year**. Besides the Himalayan region and the Indo-Gangetic plains, even peninsular India is prone to damaging earthquakes, as clearly illustrated by figure -2 (Sudhir K. Jain, 1998).

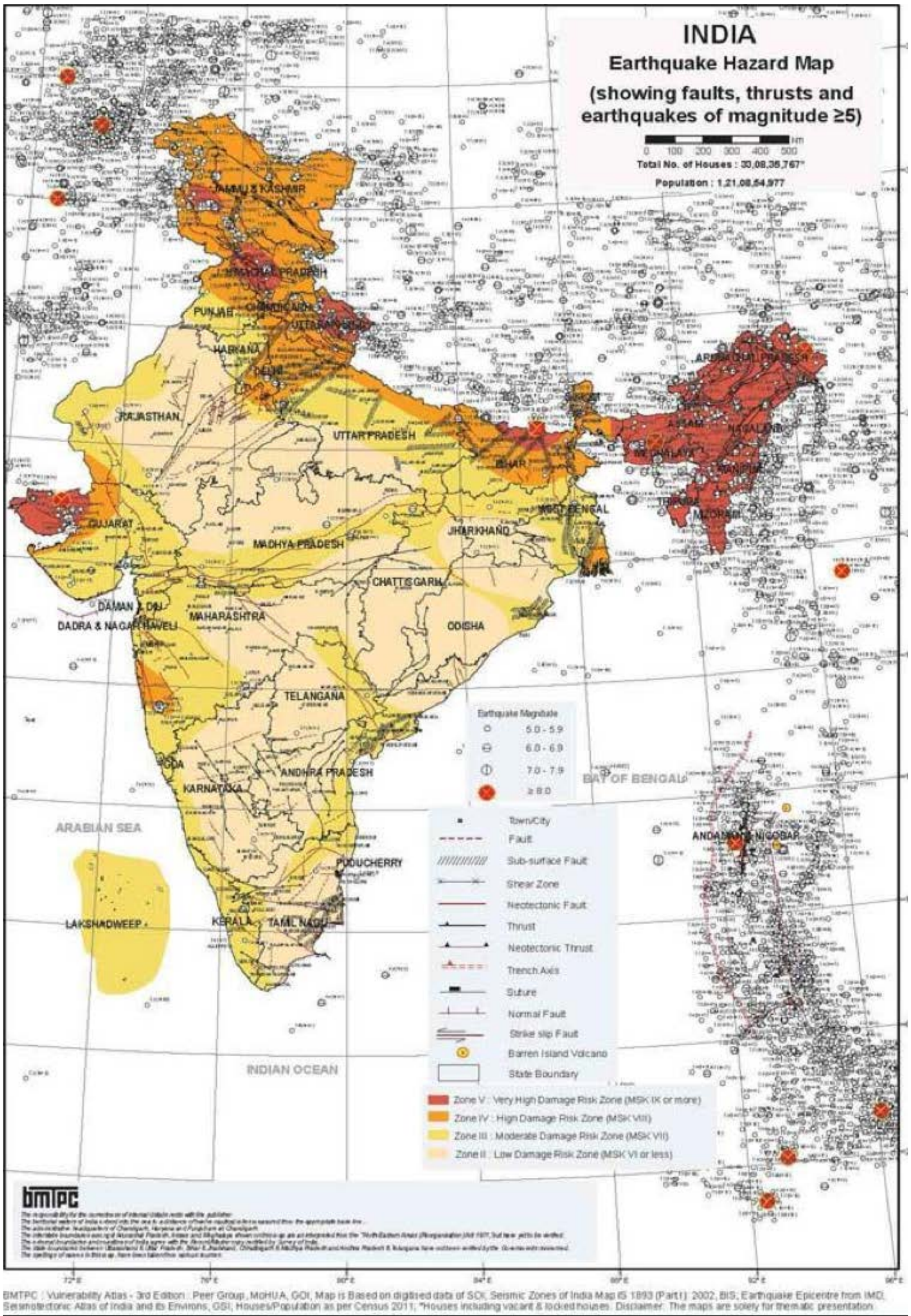


Figure 39: Earthquake Hazard Map, India

The event that falls under the category of Severe Earthquakes was also reported to be widely felt in Sikkim, Assam, Meghalaya, and northern parts of West Bengal, Bihar, parts of other eastern and northern regions of India. The epicentre lies in a seismically known and active belt called **Alpine-Himalayan Seismic Belt**. The entire area of **Sikkim** lies in **Zone IV** of the Seismic Zonation Map of India. The seismic Zone IV is broadly associated with seismic intensity VIII on the Modified Mercalli Intensity (MMI) Scale(Disaster Mitigation and Management Centre, 2012).

Some Significant Earthquakes in India (1900-2013)[1, 7, 8]

Date	Location	Disaster		Number	
		Type	Subtype	Killed	Affected
04 April 1905	Kangra, HP	Earthquake (seismic activity)	Earthquake (ground shaking)	20000	
15 Jan 1934	Bihar- Nepal Border	Earthquake (seismic activity)	Earthquake (ground shaking)	600	
15 Aug 1950	Arunachal Pradesh- China Border	Earthquake (seismic activity)	Earthquake (ground shaking)	1500	
21 July 1956	Anjar, Gujarat	Earthquake (seismic activity)	Earthquake (ground shaking)	113	219
10 Dec 1967	Koyna, Maharastra	Earthquake (seismic activity)	Earthquake (ground shaking)	117	52272
24 Aug 1980	Jammu	Earthquake (seismic activity)	Earthquake (ground shaking)	13	40
20 Nov 1980	Sikkim, Gangtok Region	Earthquake (seismic activity)	Earthquake (ground shaking)		8
31 Dec 1984	Cachar district (Assam)	Earthquake (seismic activity)	Earthquake (ground shaking)	20	10900
26 April 1986	Dharmsala	Earthquake (seismic activity)	Earthquake (ground shaking)	6	30
06 Aug 1988	Manipur-Myanmar Border	Earthquake (seismic activity)	Earthquake (ground shaking)	2	12
21 Aug 1988	Bihar- Nepal Border	Earthquake (seismic activity)	Earthquake (ground shaking)	382	20003766
20 Oct 1991	Uttarkhashi, Uttarakhand	Earthquake (seismic activity)	Earthquake (ground shaking)	1500	54383
30 Sept 1993	Latur- Osmanabad, Maharshtra	Earthquake (seismic activity)	Earthquake (ground shaking)	9748	30000
22 May 1997	Jabalpur, MP	Earthquake (seismic activity)	Earthquake (ground shaking)	43	156500
29 Mar 1999	Chamoli Dist, UK	Earthquake (seismic activity)	Earthquake (ground shaking)	100	477894
26 Jan 2001	Bhuj, Gujarat	Earthquake (seismic activity)	Earthquake (ground shaking)	20005	6321812
26 Dec 2004	Tamil Nadu, Andaman & Nicobar Island, Andhra Pradesh, Kerala	Earthquake (seismic activity)	Tsunami	16389	654512
08 Oct 2005	Kashmir	Earthquake (seismic activity)	Earthquake (ground shaking)	1309	156622
18 Sept. 2011	Sikkim	Earthquake (seismic activity)	Earthquake (ground shaking)	112	575200
01 May 2013	Doda district (J&K)	Earthquake (seismic activity)	Earthquake (ground shaking)	3	59350

Table 21: Earthquake Inventory India (1900-2013)

Source: https://nidm.gov.in/easindia2014/err/pdf/earthquake/about_ear.pdf

5.2.1 Earthquake in Meghalaya

According to Global Seismic Hazard Assessment Program (GSHAP) data, the State of Meghalaya falls in a region of high to very high seismic hazard. As per the 2002 Bureau of Indian Standards (BIS) map, this State also falls in Zone V.

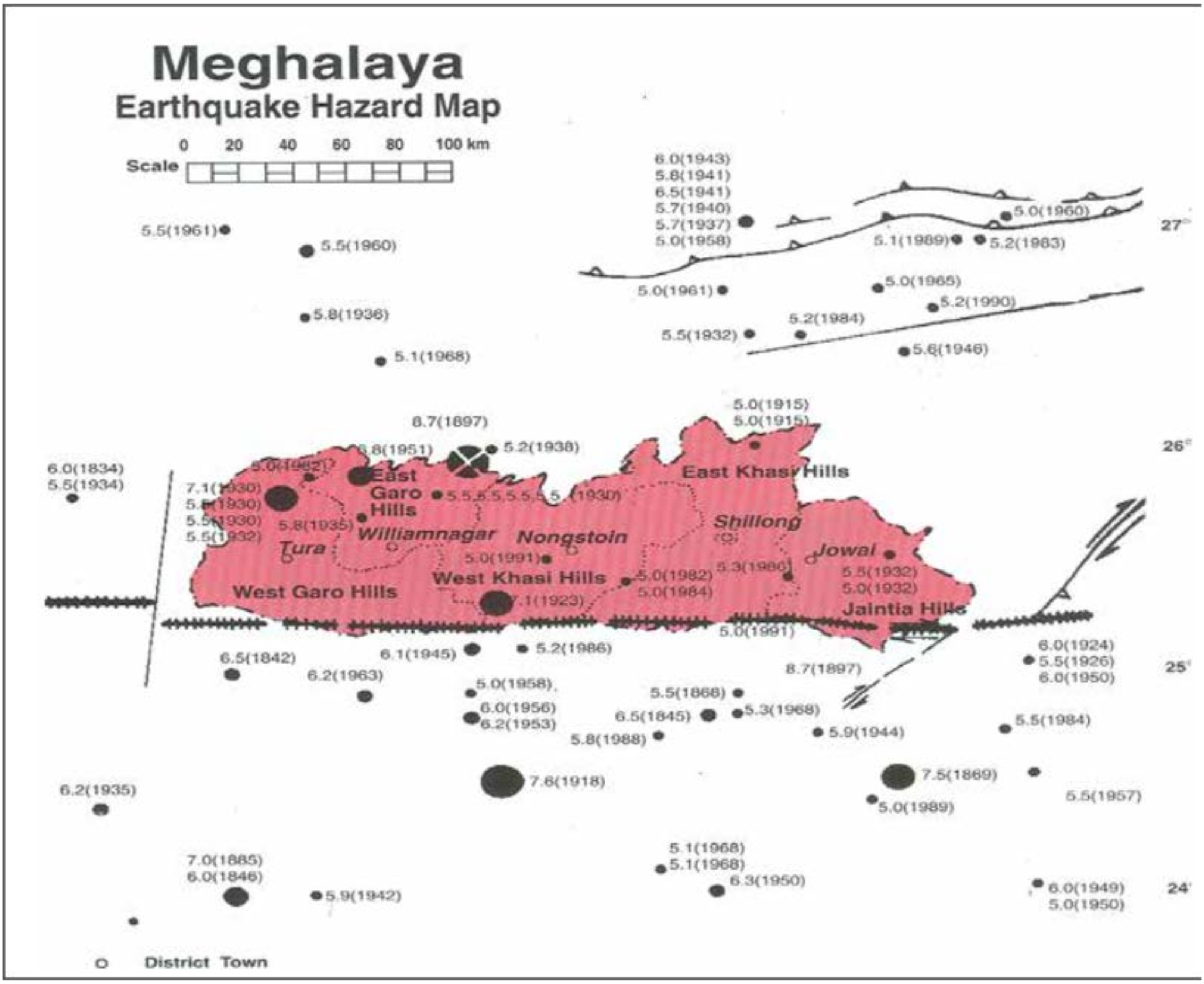


Figure 40: Earthquake Hazard Zone Meghalaya

The State of Meghalaya has witnessed seismic events of '8.7 magnitudes in 1897'. This region has been identified as a potential site of a future catastrophic earthquake. With the growth of population and infrastructure, seismic vulnerability has increased, and previous earthquakes have provided a glimpse of the devastating potential of seismic tremors (MSDMA, 2016).

5.3 Earthquakes in Shillong city

Shillong city lies on the Shillong Plateau. The Shillong Plateau experienced the 1897 Great Assam Earthquake (also known as the 1897 Great Shillong earthquake) of magnitude 8.1 and heightened seismicity from 1869 to 1950 (RMSI, 2019). As per the Bureau of Indian Standards (BIS) code IS:1893 (2016), the city is located in seismic zone V (highest). The BMTPC Atlas of 2016 is again in a very high earthquake risk zone category. In recent times, on Jan 04, 2016, an earthquake of magnitude 6.7 occurred 29 km west of Imphal, Manipur, which was severely felt in different parts of Shillong city, causing panic and minor non-structural damages in a few buildings. Another earthquake on April 13, 2016, with a magnitude of 6.8, occurred in Myanmar, and its tremors were distinctly felt in Shillong city. The city is highly vulnerable to earthquakes due to the poor construction of public buildings and houses, especially in densely populated areas of the city (RMSI, 2019).

5.3.1 Causes of Earthquake

Shillong city lies on the Shillong Plateau (SP). The SP in the north-eastern region of India is one of the most seismically active regions in the world. Several of India's past reported major and great earthquakes have originated in the SP and caused widespread damages (O. Baro, A. Kumar, 2015). The Earthquake is mainly occurring along the line of faults, joints, cracks and likewise.

The high seismic activity of the plateau is attributed to the presence of several faults around the plateau. The Dauki fault, the Dapsi thrust and the Kopili fault have been the source of past major to great earthquakes. In particular, the Kopili fault has shown active seismicity based on the evidence from the last century till the present (O. Baro, A. Kumar, 2015). Moreover, Shillong consists of low-grade metamorphic rocks of Shillong group comprising quartzite with sub-ordinate phyletic of high foliation and slates and conglomerate.

In addition to the natural factors, the damage is further aggravated by anthropogenic factors like building on areas with soil less than 30mtrs, ignoring the degree of slope differing from east to west, uneven growth pattern and need-based planning systems.

5.3.3 Earthquake Incidences

Historical and instrumentally recorded data on earthquakes show that the Shillong and adjoining area lies in a region prone to be affected by moderate to great earthquakes in the past. Some significant earthquakes that have affected the region are:

S.No.	Name	Date	Magnitude
1	Cachar Earthquake	10.01.1869	M: 7.5
2	Great Assam earthquake	12.06.1897	M: 8.7
3	Dhubri Earthquake	02.07.1930	M: 7.1
4	Bihar-Nepal Border Earthquake	15.01.1934	M: 8.3
5	Arunachal Pradesh – China Border Earthquake	15.08.1950	M: 8.5
6	Nepal-India Border Earthquake	21.08.1988	M: 6.4
8	Bhutan Earthquake	21.09.2009	M:6.2

Table 22: Earthquake incidences

5.4 Earthquake Susceptible Zonation

The most important natural factors affecting earthquake hazards are fault lines, lithology, slope degree, and proximity to faults. The physical dimension is the most tangible dimension of the role of urban planning in reducing the impact of earthquakes. One of the most important physical dimensions is the urban structure and urban land use.

The well-known statement "Earthquakes don't kill people; buildings do" highlights the need to make our communities more earthquake resilient.

5.4.1 Existing Earthquake Vulnerability Assessment

Multi-Hazard Risk and Vulnerability Assessment Report and risk atlas of Shillong City (Meghalaya) were carried out as part of the ongoing GOI-UNDP Disaster Risk Reduction (DRR) Programme to strengthen the institutional structure to undertake disaster risk reduction activities at various levels and to develop preparedness for recovery. The report provides findings of hazard mapping and analysis of key natural hazards the city is exposed to, namely– earthquake, flood, landslide, thunderstorm (associated with strong wind, lightning, hailstorms and cloudbursts), cold wave, heat-wave, fire, and climate change impact on hydro-meteorological hazards.

In GIS analysis, the landslide susceptibility map is directly overlaid with exposure data, and all exposure that falls within the high hazard zone is considered to be at high risk (worst case scenario)
Mapping methodology has not been clearly stated in the document.

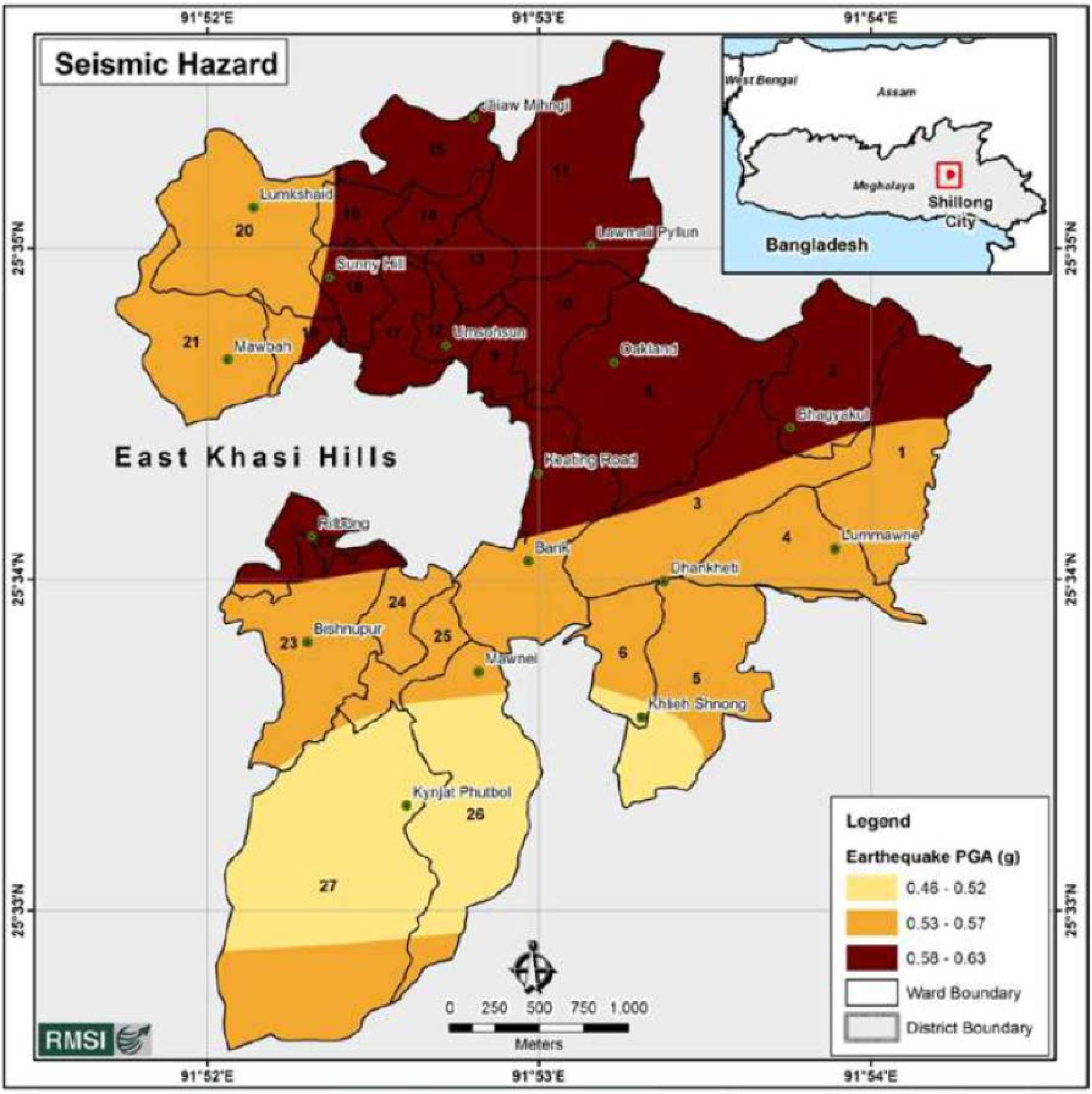


Figure 41: Earthquake susceptibility map of Shillong, Source: CDMP, Shillong 2018

5.4.2 Current Study

To map the earthquake susceptible zones, Slope, Soil, Geology, Building Density, Elevation, Isoseismic maps were developed on a scale of 1: 4000, and the maps are overlaid. Weightage has been given to each aspect to procure highly susceptible areas and those with very low susceptibility to landslides. GIS-based MCDA technique used to develop cadastral maps for a scale of 1:4000 and map the hazard/disaster wise vulnerable zones of the Shillong urban agglomerations.

5.4.3 Methodology

Multi-Criteria Decision Making problem typically involves criteria of varying importance to decision-makers. Consequently, information about the relative importance of the criteria is required. This is achieved by assigning a weight to each criterion. Ratio Estimation Procedure identified by rating method (Easton 1973) has used for identification of hazardous area.

- For Mapping of earthquake susceptibility, six criteria were selected. These principal criteria are Slope, Soil, Geology, Building Density, Elevation, Isoseismic.
- For the susceptibility map, it is necessary to give some score to each of the criteria or Layer as per their suitability.
- A matrix of calculation has been done to normalize the weight. While normalizing the weight, it should be careful that the sum of the normalized weight comes as 1.
- All six criteria were reclassified into five classes and converted to vector layers. The class weight has been given to each class of individual vector layers according to their importance. The final susceptibility map was prepared by the following formula:

Earthquake Susceptibility Map= ∑ [Criteria map * Weight]

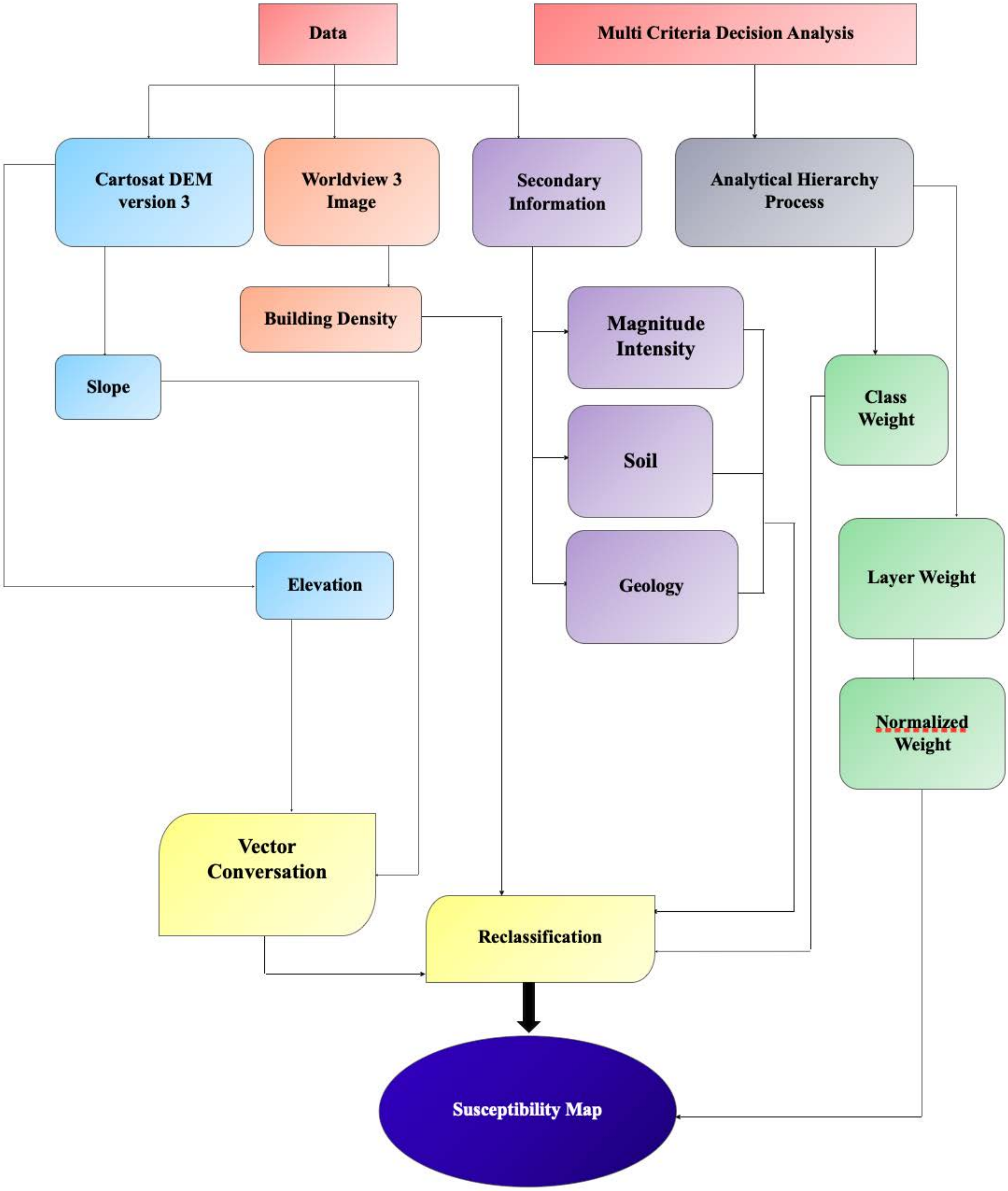


Figure 42: Mapping methodology | Source: NESAC

5.4.4 Slope

The slope is one of the main parameters in the slope stability analysis (Lee and Min, 2001) (Cevik and Topal, 2003) (Yalcin, 2008). The slope angle directly affects landslides; thus, it is used in preparing landslide susceptibility maps. In some recent studies, this parameter has been considered the most important factor in landslide susceptibility mapping. The slope map was prepared using Cartosat version 3 DEM in Arc GIS 10.3 software. For preparing a multi-hazard map of Shillong, the slope map was divided into five slope categories: very low (0-7o), low (7.1 o -14 o), medium (14.1 o -21 o), high (21.1 o -35 o) and very high (>35 o). The highest slope of the study area is 81°.

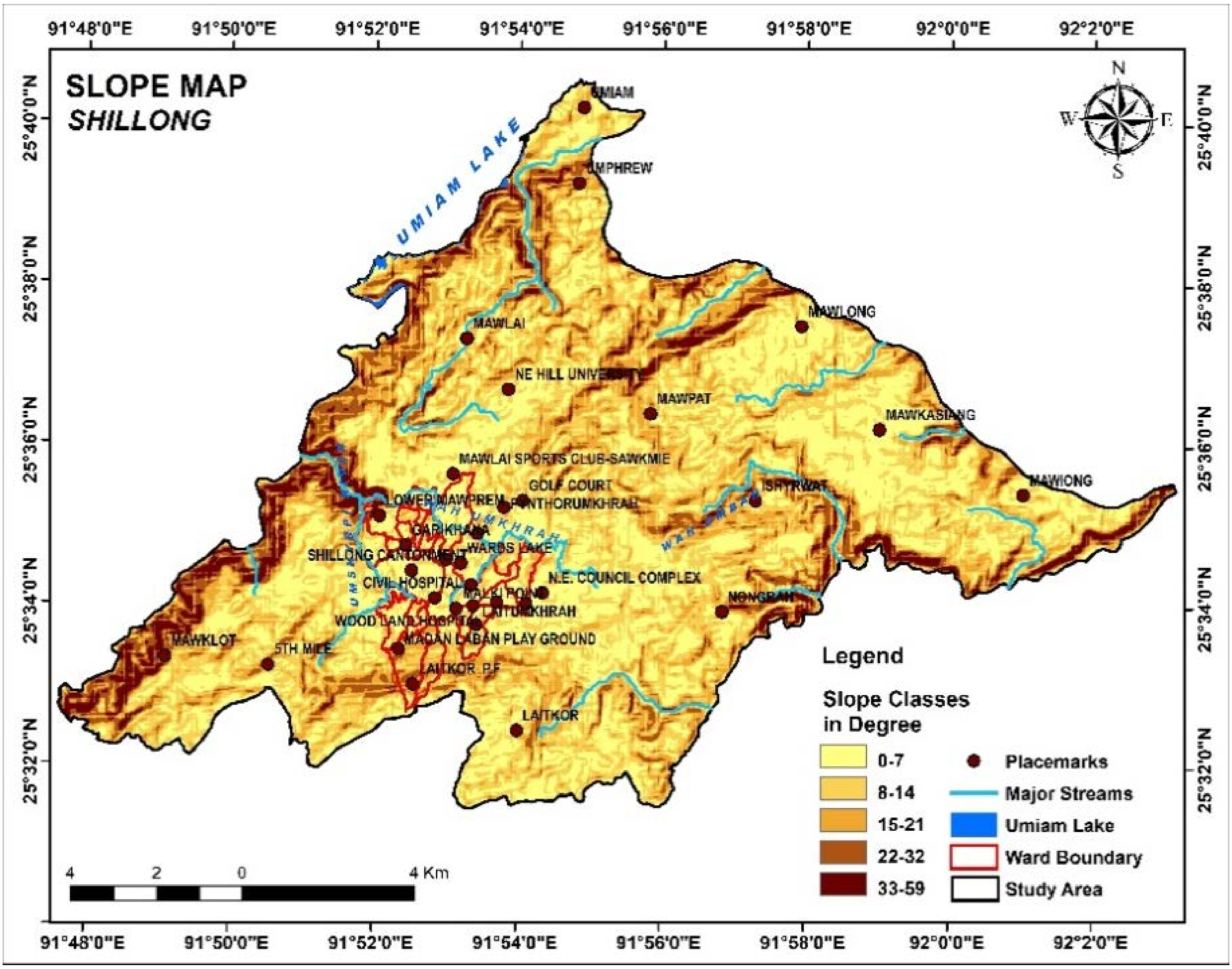


Figure 43: Slope Map, Shillong

Source: NESAC

5.4.5 Soil Stability

Soil texture and depth influence slope stability. On a micro-scale, the rate of water movement in hillslopes soils is best characterized by hydraulic conductivity. Clayey soils and compact silty soils with very small interstitial pores have much lower hydraulic conductivity values than coarse-textured soils. The hydraulic conductivity of a confining layer underlying unstable landforms regulates long-term drainage and thus controls the moisture content of the overlying soil mantle (Sidle et al., 1985). When a permeable layer is confined within a clayey matrix, pore pressures can accumulate, leading to slope failure. Additionally, highly porous moderately deep soils on very steep slopes may become unstable after extended periods of rainfall even if positive pore pressures do not develop (Sidle and Ochiai, 2006). The soil map was prepared from the following

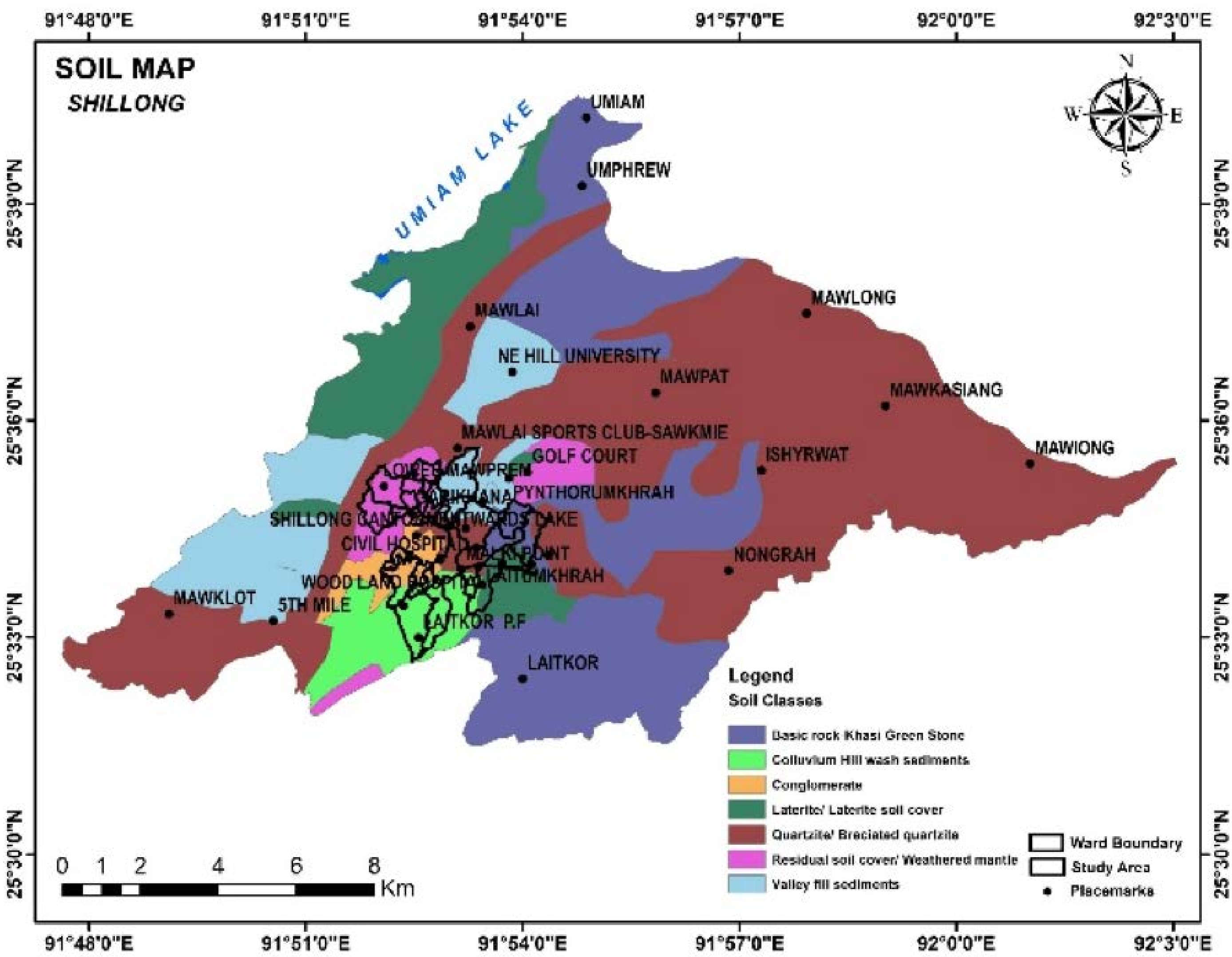


Figure 44: Soil Map Shillong

Source: NESAC

5.4.6 Building Density

The Building density map is a very vulnerable earthquake hazard. Because if an earthquake happens, the probability of damages is more in a highly dense area.

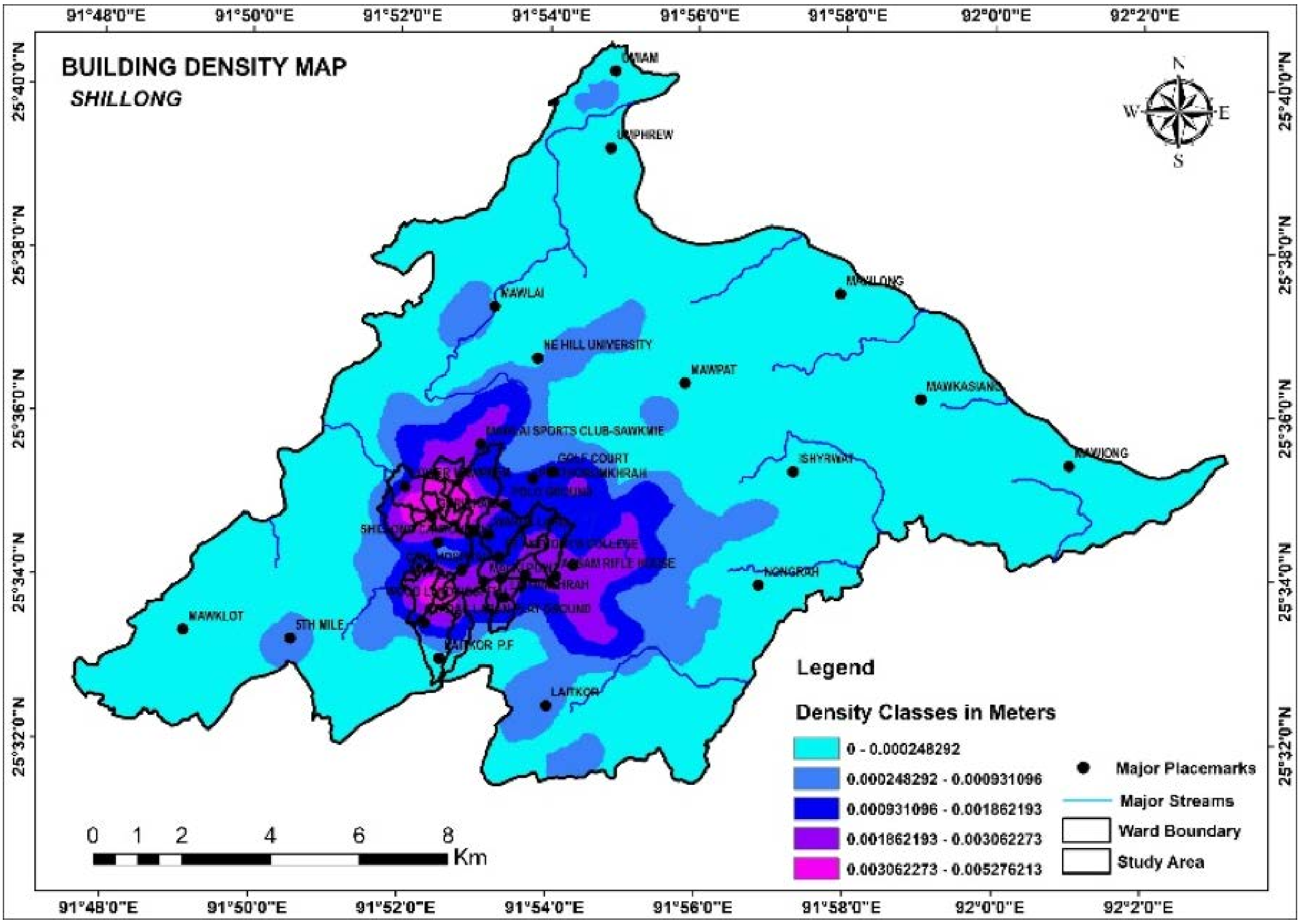


Figure 45 Building Density Map Shillong

Source: NESAC

5.4.7 Elevation

The elevation is useful to classify the local relief and locate points of maximum and minimum heights within terrains. To calculate flood and landslide densities for different relief classes of Shillong, the relief map was divided into five altitude classes: 625-1048 m, 1048-1327 m, 1327-1621 m, 1621- 1981 m, 1981-2588 m. o calculate flood and landslide densities for different relief classes of Shillong, the relief map was divided into five altitude classes: 861-1087.25 m, 1087.25- 1239.46 m, 1239.46-362.87 m, 1362.87 -1494.51 m, 1494.51 -1654.94 m, 1654.94.-1910 m. The Shillong agglomeration covers an elevation range from 861-1910 m.

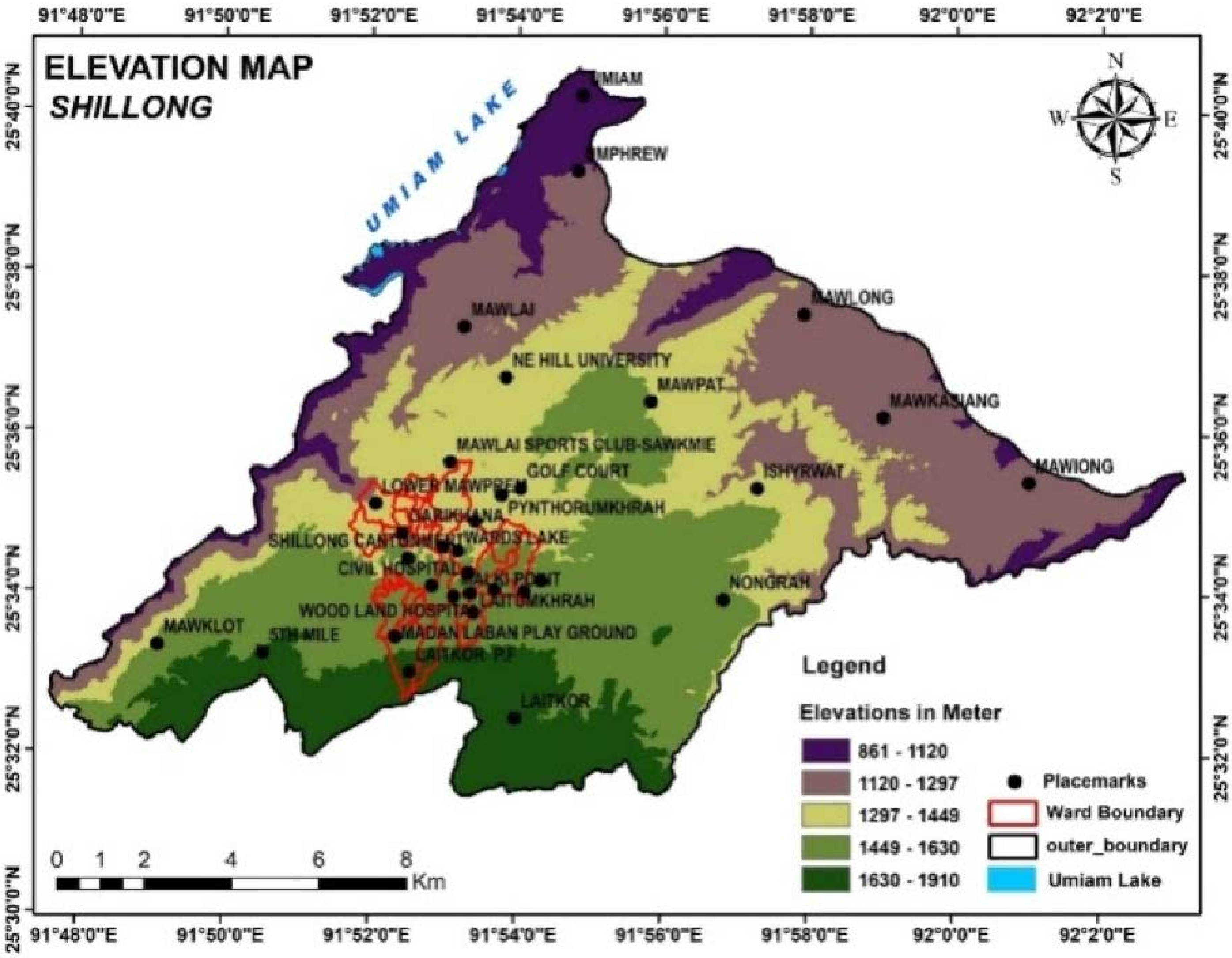


Figure 46: Elevation Map, Shillong
Source: NESAC

5.4.8 Isoseismal

An Isoseismal is a contour or line on a map connecting points of equal intensity relating to a specific earthquake and confining the area within which the intensity is the same. The Isoseismal map was prepared using the spatial interpolation method (Schenkova et al., 2007; Sivakumar et al., 2017). In this study area, the highest intensity shows 4.55Mag, and the lowest is 4.30 Mag.

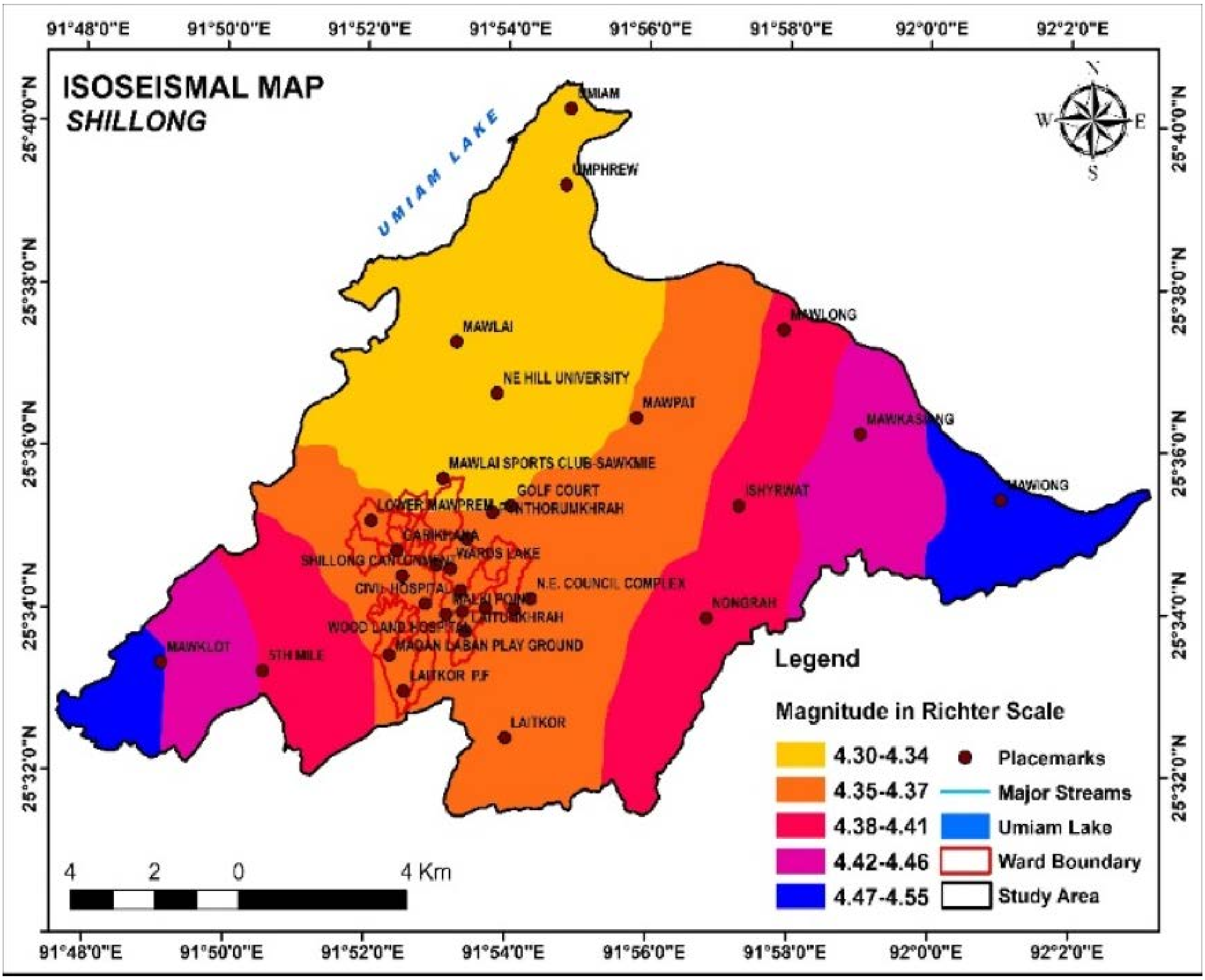


Figure 47: Isoseismal Map Shillong

Source: NESAC

5.5 Ward Level Vulnerability

As per the Seismic Zoning Map of India (IS: 1893, 2002, 2014), Shillong city is located in the highest seismic Zone-V. Faults present within Meghalaya Plateau include the Barapani shear zone, the Chedrang fault, the Samin fault, the Dapsi thrust, and the Dudhnoi fault (Kayal et al., 2006) (Angelier and Baruah, 2009) . The faults surrounding the SP are the Dauki fault in the south, the Dhubri fault in the west, and the Kopili fault in the east. According to (Biswas et al., 2013), Barapani Shear Zone is one of the major active thrust faults in this region. The Dauki fault is more than 300 km long and dips towards the south as a normal fault (Srinivasan, 2005). The Ms 7.1 Meghalaya earthquake of Sept 9, 1923, occurred on this fault. This earthquake caused heavy damage in the southern part of Meghalaya, including Cherrapunji, Guwahati, Sivasagar and Borjuli in Assam, and Mymensingh and Nagrakata in West Bengal. On April 13, 2016, an earthquake of magnitude 6.7 occurred 29 km west of Imphal, Manipur, severely felt in different parts of Shillong city, causing panic and minor non-structural damage in a few buildings in Shillong. The NE India was subjected to severe shaking by several damaging earthquakes. The systematic account of which is available from the 19thcentury. North-East India region lies in one of the seismically active regions of the world. Some of the well-known earthquakes that have occurred in North-East India include the 1869 Mw 7.5 Cachar earthquake, 1897 Mw 8.1 Great Assam earthquake (also known as 1897 Shillong earthquake; Bilham and England, 2001, 1923 Ms 7.1 Meghalaya earthquake, 1930 Ms 7.1 Dhubri earthquake, 1943 Ms 7.2 Assam earthquake, 1947 Ms 7.7 Arunachal Pradesh earthquake, 1950 Mw 8.7 Assam earthquake, 1988 Ms 7.3 Manipur earthquake, 2009 Mw 5.1 Assam earthquake, 2011 Mw 6.9 Sikkim earthquake, and the recent 2016 Mw 6.7 Imphal, Manipur earthquake.

To get the final site response of the earthquake map of Shillong agglomeration, six factors, namely
Isoseismal area, Building Density and Geomorphology map has been given the rank of each class of the layers based on onsite response to Earthquake. Weights to each factor have been assigned based on importance and the analytical hierarchy approach. For Shillong, the Isoseismal area and Slope have been given the highest weight, and elevation was the lowest. The result of the map is derived from the equation (1) by using the raster calculator in Arc.GIS 10.3. The site response contains numerical susceptibility information where the highest value indicates high susceptibility and the lower value indicates low susceptibility. The site response values were then divided into five zones, including “Very Low”, “Low”, “Medium”, “High”, and “Very High”.

S.No.	Rating method	Normal Weight
1	Slope	0.18
2	Soil Stability	0.15
3	Elevation	0.13
4	Geology	0.20
5	Isoseismal	0.18
6	Building Density	0.16
	SUM	**1**

Table 23: Earthquake Susceptibility weightage

Hazard Classes	Ward	Number
Very High	6 ,9,10,11 ,12,13,14,15,16,17, 18,19, 20,21,23,25, 26,27	18
High	1,2,3,4,5,7,8 ,22	8
Medium	24	1
Low	Nil	Nil
Very Low	Nil	Nil

Table 24: Ward wise Earthquake vulnerability

We find that the 18 wards have a very high susceptibility to earthquakes, followed by the other wards falling in the high susceptibility category and 24 wards in the medium category. All the wards in the city are either very high or highly susceptible to earthquakes; no ward falls under the low or very low category. This indicates that the majority of wards are extremely vulnerable to earthquakes.

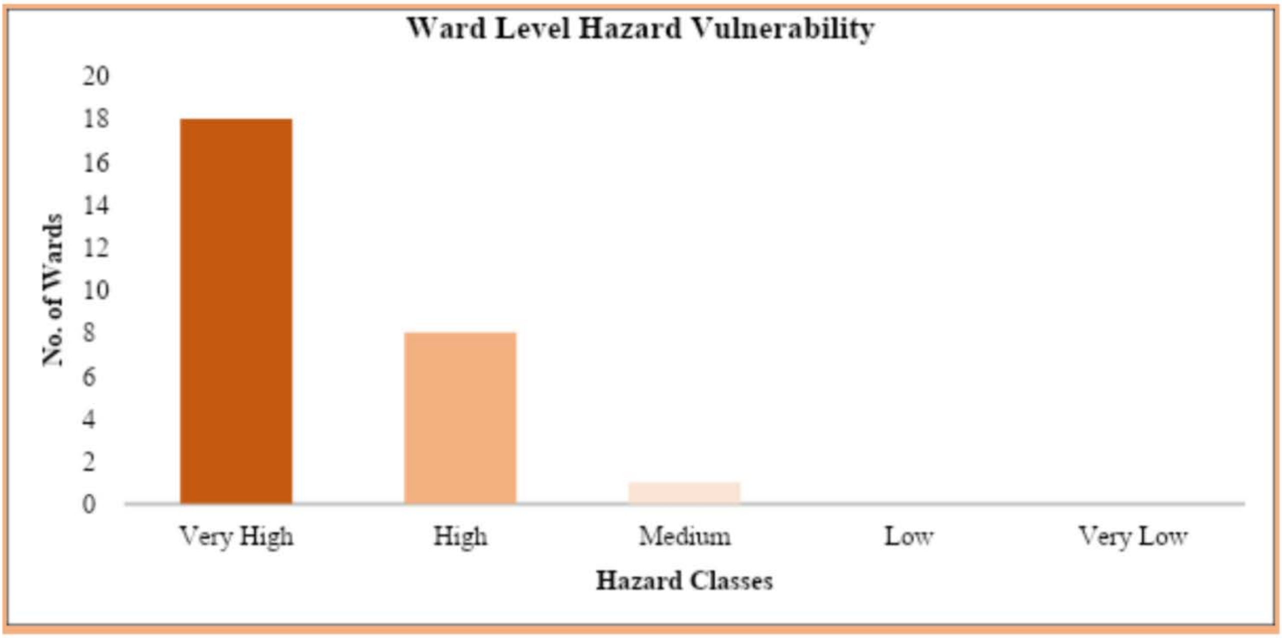


Figure 48: Ward-level Hazard Vulnerability

The result determines that the majority of wards are vulnerable to earthquake susceptibility. The building stocks are much vulnerable due to over crowd and high multi-storeyed building. This may take huge damage probability in the near future earthquake. Most of the houses in Shillong city have not incorporated building bye-laws and do not have the adequate structural strength to withstand a large earthquake (Meghalaya Urban development Department, 2016)). High-risk zones are due to haphazardly construction of buildings and numbers of encroachment of residents. The alarming growth of population and increasing numbers of building constructions in these localities also increase damage estimation in the future.

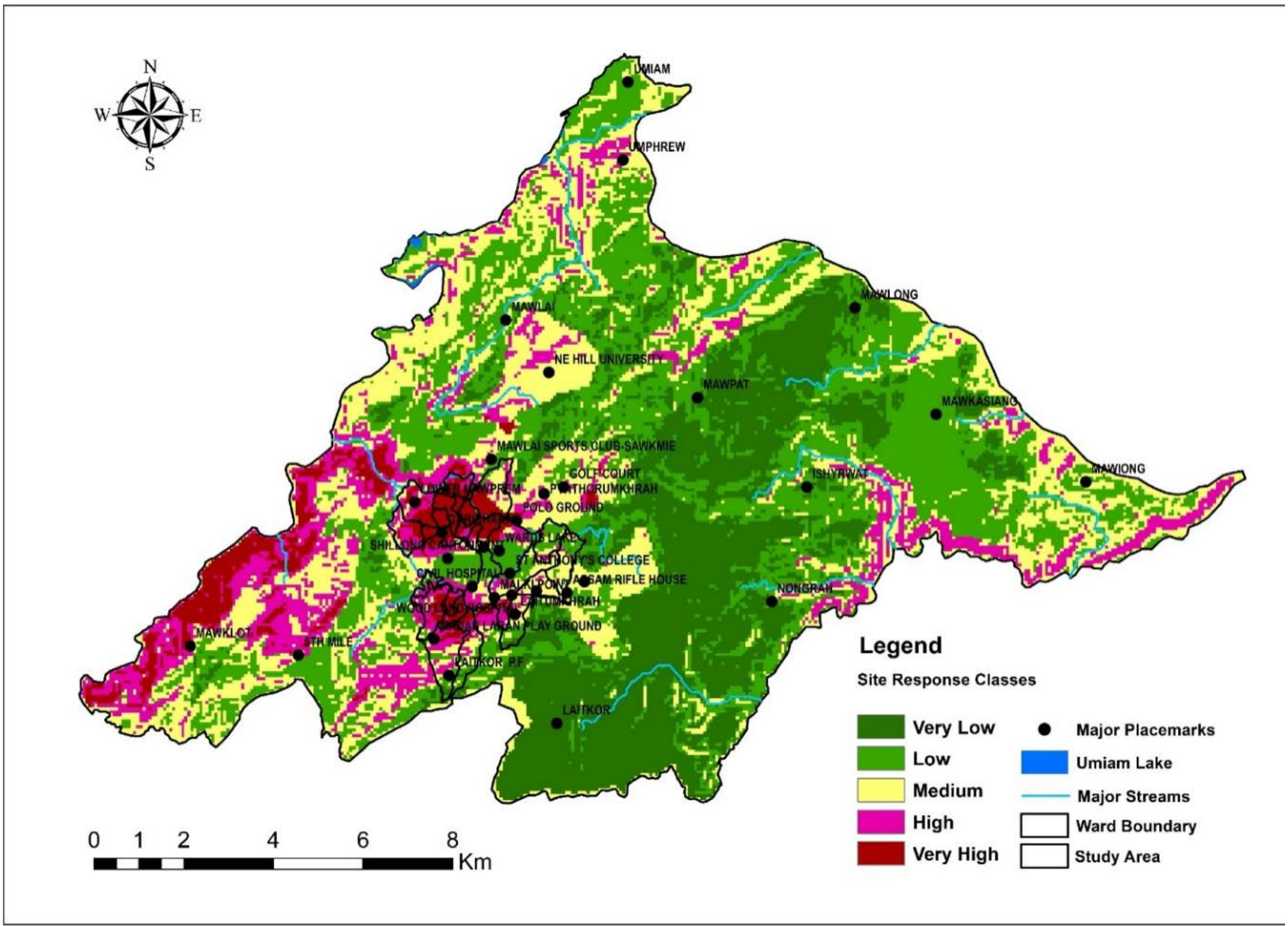


Figure 50: Earthquake Susceptibility Map – Shillong | Source: NESAC

5.6 Vulnerability to Earthquakes

5.6.1 Major earthquake events and their impact

Shillong city lies on the Shillong Plateau (SP). SP has experienced heightened seismicity from 1869 to 1950. Since 1951, Shillong city and nearby areas have been experiencing moderate to high level of seismicity (RMSI, 2019). Episodes are often felt severely in different parts of Shillong city, causing panic and minor non-structural damage in a few buildings.

S.No.	Name	Year	Magnitude
1	Cachar Earthquake	1869	M: 7.5
2	Great Assam earthquake	1897	M: 8.1
3	Meghalaya Earthquake	1923	M: 7.1
4	Dhubri Earthquake	1930	M: 7.1
5	Assam Earthquake	1943	M: 7.2
6	Arunachal Pradesh Earthquake	1947	M: 7.7
7	Assam Earthquake	1950	M: 8.7
8	Manipur Earthquake	1988	M:7.3
9	Assam earthquake	2009	M 5.1
10	Sikkim Earthquake	2011	M 6.9
11	Imphal Manipur Earthquake	2016	M 6.7

Table 25: Major earthquakes felt in the city

5.7 Population Vulnerability

In terms of the earthquake susceptible zones, we can trace the vulnerable population to earthquake events. We find that almost 75.75% of the city population lie in the very High earthquake demarcated areas, followed by 22.34% of the population in the high hazard-prone area and the only ward (No. 24) falls into the category of medium susceptibility. All the wards are prone to earthquake, so no one falls into the low or very low category.

Hazard Classes	Ward No	Ward Name	Total Population	%	Total
Very High	6	Malki	4888	2.61	75.75
	9	Police Bazar	2145	1.15	
	10	Jail Road	5766	3.08	
	11	Jail Road	48643	26.01	
	12	Mawkhar	2797	1.50	
	13	Mawkhar	5337	2.85	
	14	Jaiaw	3032	1.62	
	15	Jaiaw	3838	2.05	
	16	Jaiaw	4067	2.17	
	17	S.E.Mawkhar	3270	1.75	
	18	S.E.Mawkhar	3875	2.07	
	19	Mawprem	4556	2.44	
	20	Mawprem	10613	5.68	
	21	Mawprem	14009	7.49	
	23	Kench's Trace	8161	4.36	
	25	Laban	5218	2.79	
	26	Lumparing	6319	3.38	
	27	Lumparing	5133	2.74	
High	1	Laitumkhrah	11537	6.17	22.34
	2	Laitumkhrah	3266	1.75	
	3	Laitumkhrah	5437	2.91	
	4	Laitumkhrah	2753	1.47	
	5	Malki	4908	2.62	
	7	European Ward	4891	2.62	
	8	European Ward	6009	3.21	
	22	Kench's Trace	2973	1.59	
Medium	24	Laban	3568	1.91	1.91
Low	Nill				
Very Low	Nill				
Total			187009		100.00

Table 26: Household and Total Population Vulnerability

Chapter 6

Critical Infrastructure Mapping & Assessment & Urban Planning

6.1 Critical Infrastructures Mapping

The urban infrastructure provides a backbone for the functioning of a city. Its preparedness towards disaster resilience is directly dependent on the present status of its physical infrastructure and services. Govt. of India has set Service Level Benchmarks for urban infrastructure - water supply, sewerage, solid waste management, and stormwater drainage facilities and is striving towards bridging the gaps in infrastructure and services deficit in cities through various schemes.

Smart City Mission, introduced in 2014, aimed to promote cities that provide core infrastructure and give a decent quality of life to their citizens, a clean and sustainable environment in the cities. Under the 4th round of Smart cities mission 2017-18- 2020-21, Shillong aimed "to transform Shillong into a cultural and economic hub in Meghalaya with a focus on tourism and culture and to make it a liveable, clean, green, inclusive, modern, safe and citizen-friendly and well-governed city".

Critical Infrastructure refers to the primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency. Critical facilities are elements of the infrastructure that support essential services in a society. They include such things as transport systems, air and seaports, electricity, water and communications systems, hospitals and health clinics, and centres for fire, police and public administration services" CITATION UNI09 \l 16393 (UNISDR, 2009).

Socio-economic infrastructures include:

- Schools
- Hospitals
- public administration
- disaster management services
- recreational areas

Its significance determines the degree of criticality of infrastructure in relation to the effects on society in case of its failure (Lenz S., 2009). Disaster resilience of these infrastructure systems during and after hazards is vital for the response and recovery to the event. These aspects are not always initially clear until the system is exposed to a hazard and climate disasters.

6.1.1 Water Supply and Sanitation

With the rapid growth of urbanization, citizens face a shortage of water in the city. The main source of water supply for Greater Shillong is **River Umium.** According to the Master Plan of Shillong 1991-2011, the available quantity of water is just sufficient to meet the demand of about fifty per cent of the total population of Shillong. The rest of the population depends upon private wells, vendor tankers and small springs. In 2006, the water supply available to the city was 28.68 mld (million litres per day) as against the demand of 51.70 mld (Bankerlang Kharmylliem and Ngamjahao Kipgen, 2018). In 2016-17, almost **77% of the households (HHs)** had a water supply connection. The **per capita water supply is low at 78 lpcd** (Smart City Proposal, 2016-17).

Despite high rainfall, many areas in Meghalaya face water shortages. Water demands rising, whereas supply is declining (Shabong, 2015). During the dry season, the water supply is irregular, as evident in most parts of the city. The amount of water that the localities receive differs in both quality and quantity.

The major issues of the current water supply systems in Shillong are inadequate availability of water supply, antiquated water infrastructure, inadequate financial resources and inefficiency in mobilizing capital by SMB and PHED (Bankerlang Kharmylliem and Ngamjahao Kipgen, 2018), absence of an integrated approach in service delivery and inability to impose user charges. The **extent of non-revenue water 58% and the water connections not metered, and only 12% of the water services cost recovered** (Smart City Proposal, 2016-17).

The city registers direct discharge of sewage into **Umshyrpi and Umkhrah**, the two highly polluted streams in Shillong city, and the Meghalaya State Pollution Control Board has monitored the water quality of the streams under the national Water Monitoring Programme and the water in the **streams under 'E' category,** indicating that it is fit only for irrigation, industrial cooling and controlled waste disposal (Meghalaya Government, 2018). With no sewage treatment plant, all the house sullage (kitchen and bathroom wastewater) drains either into the River Umshyrpi in the south or the Um Khrah in the north.

Almost **94% of the households in the city have individual & community toilet coverage,** and almost 0.57% of HHs have no facilities, hence resort to **open defecation**. Provision of **sanitary toilet facilities for this 5.82%** of households is being taken up under the "Swachh Bharat" mission (Smart City Proposal, 2016-17).

6.1.2 Solid Waste Management

The city of Shillong was ranked low under the Swachh Survekshan 2020in terms of cleanliness. The city lacks proper processing and disposal of the solid waste generated at the city level. The Municipal Solid Waste (Management and Handling) Rules, 2000, apply to all ULBs to maintain a Solid Waste Management (SWM) system within the city, **including collection, segregation, transportation, processing and disposal of waste.**

The city produces almost **159 MT of municipal solid waste per day,** accounting for 0.4 kg of waste per capita per day. The major solid waste generation sources are households (56%), markets (23%), hotels & restaurants (7%), construction waste (2%), and street sweeping (7%) (Mukhopadhyay, 2015). In the SMB area, 46% of the waste generated is collected. In comparison, outside the SMB area, the figure is only 32%, and for the entire GSPA (Greater Shillong Planning Area), the percentage of garbage collected works out to about 41%. Only **43% of households have the facility of door-to-door** collection or Community Bin facility. Presently garbage collected is disposed into the gorges of the trenching ground situated at MAWLAI on Shillong Guwahati Road (Shillong Municipal Board, 2018).

Proper collection and safe disposal of solid waste during disaster emergencies are **critical for public health**. A proper management system will facilitate the existing collection and disposal and **eradicate serious health risks post disasters.** Solid waste management is critical for improving the city resilience. **Polythene causes clogging of the drains, which further increases water logging incidents in the city.**

6.1.3 Storm Water Drainage

In today's urban India, water logging is a common concern that can lead to disaster as there is no city with 100% coverage of stormwater drainage. Urban stormwater management is an important aspect of urban development, planning and expansion. Urbanization of an area invariably leads to an increase in the overall imperviousness of the area. When the land becomes impervious, stormwater will stagnate on the surface, affecting the infrastructure, transportation and causing inconvenience to the general populace. One way to handle this is through a proper well-maintained storm drainage system (Kumar. K.P et al, 2015).

The drains in the city run for 148.91 km and drain directly into the Umkhrah and Umshyrpi rivers. At present (2016-17), storm-water drainage network coverage is less than 75% of the city, the incidence of sewerage mixing in drains is almost 100% (Smart City Proposal, 2016-17).

6.1.4 Road Network/ Connectivity

The impacts of natural hazards on roads and bridges can range from mere temporary traffic disruption to major calamities resulting in deaths, the long-term loss of access to the city, economic areas and supply and transportation of relief. The creation of resilient roads and bridges reduces the impact of specific hazards and helps to improve connectivity and communications, ensuring continued access to goods and services.

In Shillong city, the total road length of Shillong is 356 km, with a road density of 2.05 km/sq. Km (Shillong City Development Plan). NMT (Non-Motorised Transportation) has not being stressed upon in the city Comprehensive Mobility Plan (CMP) due to undulating topography & operational constraints. The National Highway (NH 44) links Shillong with Guwahati and Silchar of 103 Kms and 240 Kms respectively. Almost all the major roads, minor roads, national highways and other transport structures are regularly affected by flooding (Shillong City Disaster Management Plan, 2018).

Transport disruption:

- **A massive landslide disrupted road communication between Assam and Meghalaya along the National Highway No 6. Traffic has been the worst hit at UmkhenThangshalai Bridge- September, 2020**
- **Road communication between Assam and Meghalaya by National Highway 44 has was disrupted following a massive landslide at Sonapur near Meghalaya border – May 2018**
- **Landslides on National Highway 44 in Meghalaya's East Jaintia Hills, disrupted traffic flow, due to minor landslides at Tongseng, Ratacherra and Dona area along the NH-44 - August 2015**

Source: GSI, NIDM

6.1.5 Energy and telecommunication

One of the immediate impacts of disasters is the loss of electricity supply and can result in power shortage/ outages triggering accidents, bringing economic activity to a halt and hindering the emergency response until electricity supply is restored. A disaster like floods and landslides causes great damage and reduces accessibility to such damaged facilities, leading to repair/ recovery time from a few hours to days. Recovery and repair of such infrastructure are driven by the number of repairs required, site accessibility, wherein repair may not be initiated until the flood water recede.

The agencies responsible for the supply, management and distribution of the electricity in the city are: (1) North Eastern Regional Electricity Board, Shillong; (2) Meghalaya State Electricity Board, Shillong and (3) NEEPCO (North Eastern Electric Power Corporation Limited).

The average electricity consumption in the residential area is 300 units /house/day and in the commercial area is 450 units /shop/day. Total number of 378 Solar streetlights available under MECL No smart metering is introduced.

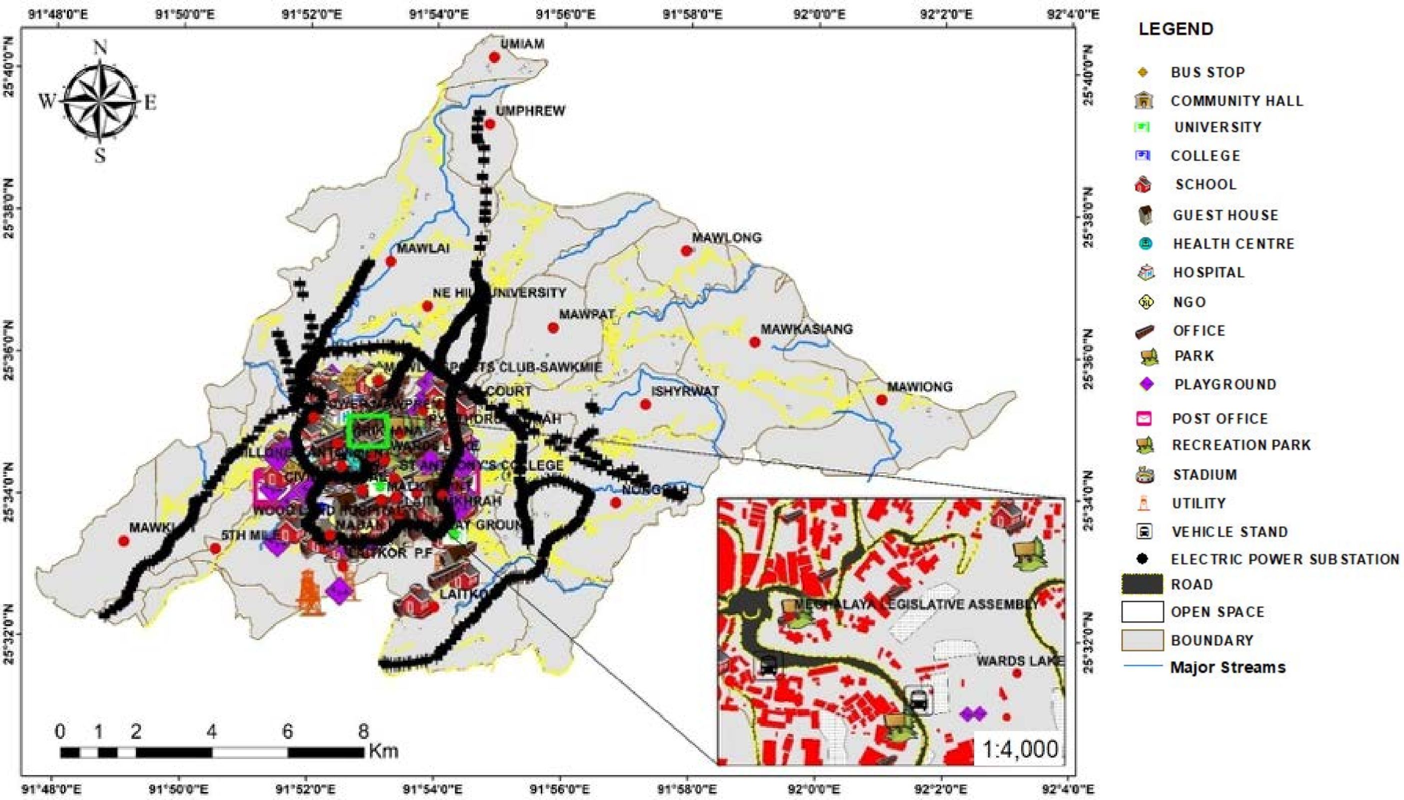


Figure 51: Critical Infrastructure, Shillong City
Source: NESAC

6.1.6 Land Use – Landcover Mapping

In an urban environment natural and human-induced environmental changes are of concern today because of environmental deterioration (M.K. Jat et al, 2008). The study of land use/land cover (LU/LC) change is very important to have proper planning and utilization of natural resources and their management (N. E. M. Asselman and H. Middelkoop, 481-499). Land-cover and land-use information are required for many different kinds of spatial planning, from urban planning at a local level up to regional development. They play an important role in agricultural policymaking (Gerd Eiden).

'Land-use refers to the various human activities carried on land, while 'land cover' refers to natural features that the land surface'

Comparing the Population density of the city with the built-up area change, it is evident that the most built-up changes have occurred in the areas with lesser population densities over the years as the more populated wards located in the northern side do not have any scope for land-use change. These wards have always been very populated, and the urbanisation in the last three decades have occurred more towards the eastern and southern parts of the municipality area.

Materials and Methods

Satellite Data used:

LANDSAT: LANDSAT is moderate spatial-resolution (30-meter) imagery that provides large areas of repeated data coverage at a scale that enables users to see detailed human-scale processes, such as urbanization. Since 1972, LANDSAT program satellites have collected consistent spectral imagery of the Earth's continents and surrounding coastal regions. This historical archive is unmatched in quality, detail, coverage, and length, enabling people to study many aspects of the planet and evaluate the dynamic changes caused by natural processes and human practices. (U.S. Geological Survey, National Aeronautics and Space Administration, 2019).

SENTINEL: Each Sentinel mission is based on a constellation of two satellites to fulfil revisit and coverage requirements, providing robust datasets for Copernicus Services. These missions carry a range of technologies, such as radar and multi-spectral imaging instruments for the land, ocean and atmospheric monitoring.
The detailed specification of the satellite data used is given below.

Image acquisition date	Satellites	Spatial Resolution
15th December 1989	LANDSAT 5 TM	30 m
19th December 1999	LANDSAT 7 ETM+	30 m
13th December 2009	LANDSAT 5 TM	30 m
8th December 2019	SENTINEL 2A	10 m

Table 27: Satellite data used for the study | Source: USGS Earth Explorer

QGIS: **QGIS** (until 2013 known as **Quantum GIS**) is a free and open-source cross-platform desktop geographic information system (GIS) application that supports viewing, editing, and analysis of geospatial data (Q GIS, 2020).

Methodology

A detailed methodology of the process is given below.

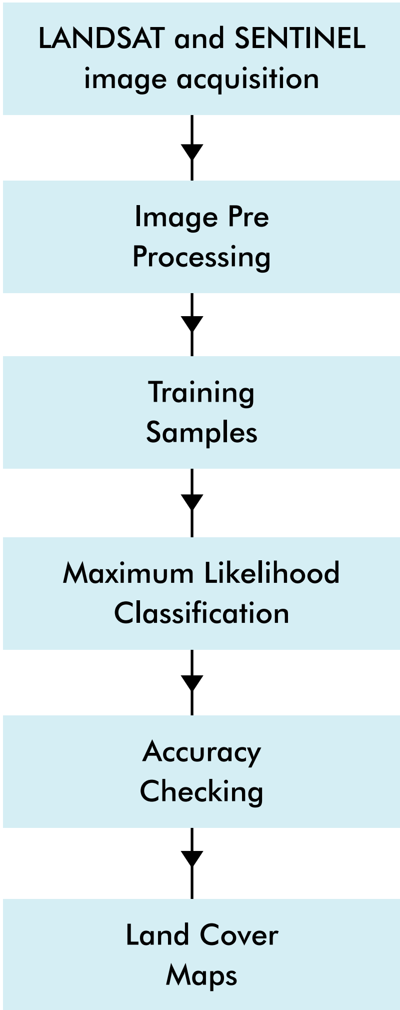


Figure 52: Mapping Methodology

LANDSAT and SENTINEL image acquisition: Landsat and Sentinel satellite images were used for developing land use maps for Shillong city. LANDSAT and SENTINEL data is freely available in high-resolution data. Sentinel 2 A was used for the year 2019 as it currently gives the highest spatial resolution (10 meters), which is freely available. Sentinel 2A images were useful to analyse the changes at the ward level. For 2009, LANDSAT 5 TM was used because scan lines were detected in the LANDSAT 7 ETM+ data. For 1999, LANDSAT 7 etm+ gave the highest spatial resolution available, and for 1989, LANDSAT 5 TM was used. The Land cover maps of the years 1989, 1999, 2009 and 2019 provide a timeframe of three decades over which substantial changes can be detected. The satellite data of these years was freely available.
The images were acquired from the USGS Earth Explorer website (https://earthexplorer.usgs.gov/). Cloud free scenes for December of each year were downloaded from the Earth explorer website. Several images were downloaded for all four years, but the month of December provided consistency in the clarity of images and dates.

Image Pre Processing: Sentinel and LANDSAT bands were converted to reflectance in QGIS pre-processing tools. It is important to convert the DN into reflectance because it still affects the light source, atmosphere, surface material, and typically we are interested in the surface materials. So, that why Atmospheric Correction (AC) comes into the pictures. After Atmospheric correction, we have the information about the surface. The bands were then imported to an arc map, where a composite image of bands was made. For Sentinel 2A, bands 2,3,4 (blue, green, red) and 8 (NIR) were chosen to have a spatial resolution of 10m. For LANDSAT 5 and LANDSAT 7, bands 2,3,4 (blue, green, red) were chosen to have a spatial resolution of 30 meters. The composite images were then clipped according to the present boundaries of the Municipality provided by NESAC.

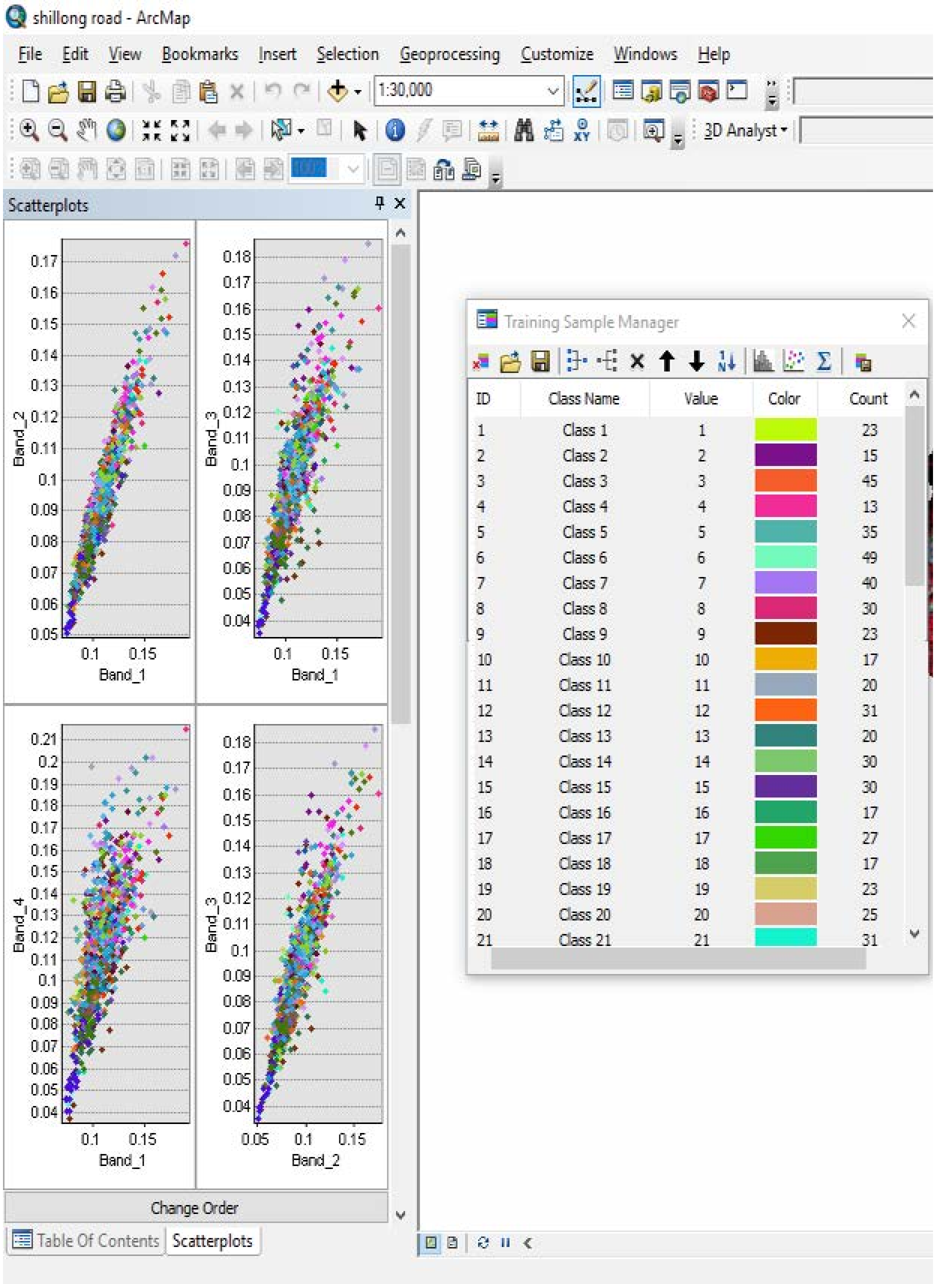


Figure 53:Scatter plots for Built-up area 2019

Training Samples: Various training samples were created for the land cover categories of Built-up and Vegetation areas. Training samples were chosen visually based on high resolution google earth imagery. After collecting and merging the training samples for the classes of built-up and vegetation, the signature file was created, which was later used during the classification. Scatterplots were used to compare the multiple training samples to see the separability and distribution of the samples.

Maximum Likelihood Classification: The maximum likelihood (ML) classification method was applied to produce land cover maps for the selected years. Here we have considered only two classes- Built-up area and Vegetation area to determine the changes in the increase of built-up area over three decades. This is one of the most accurate classification methods in remote sensing in which a pixel with the maximum likelihood is classified into the required class.

Accuracy Checking: The built-up and Vegetation shapefiles were converted into kml format and overlaid on Google Earth map to check the accuracy. The land cover maps prepared on GIS were found to portray the actual land cover on Google earth.

Results and Discussion: The process gives the Land cover maps of 1989, 1999, 2009 and 2019 (Fig6). The shapefiles for each year were colour categorised as built-up area and area under vegetation. The main aim of the exercise was to detect the urban sprawl, so only two class categories were sufficient for the approach.

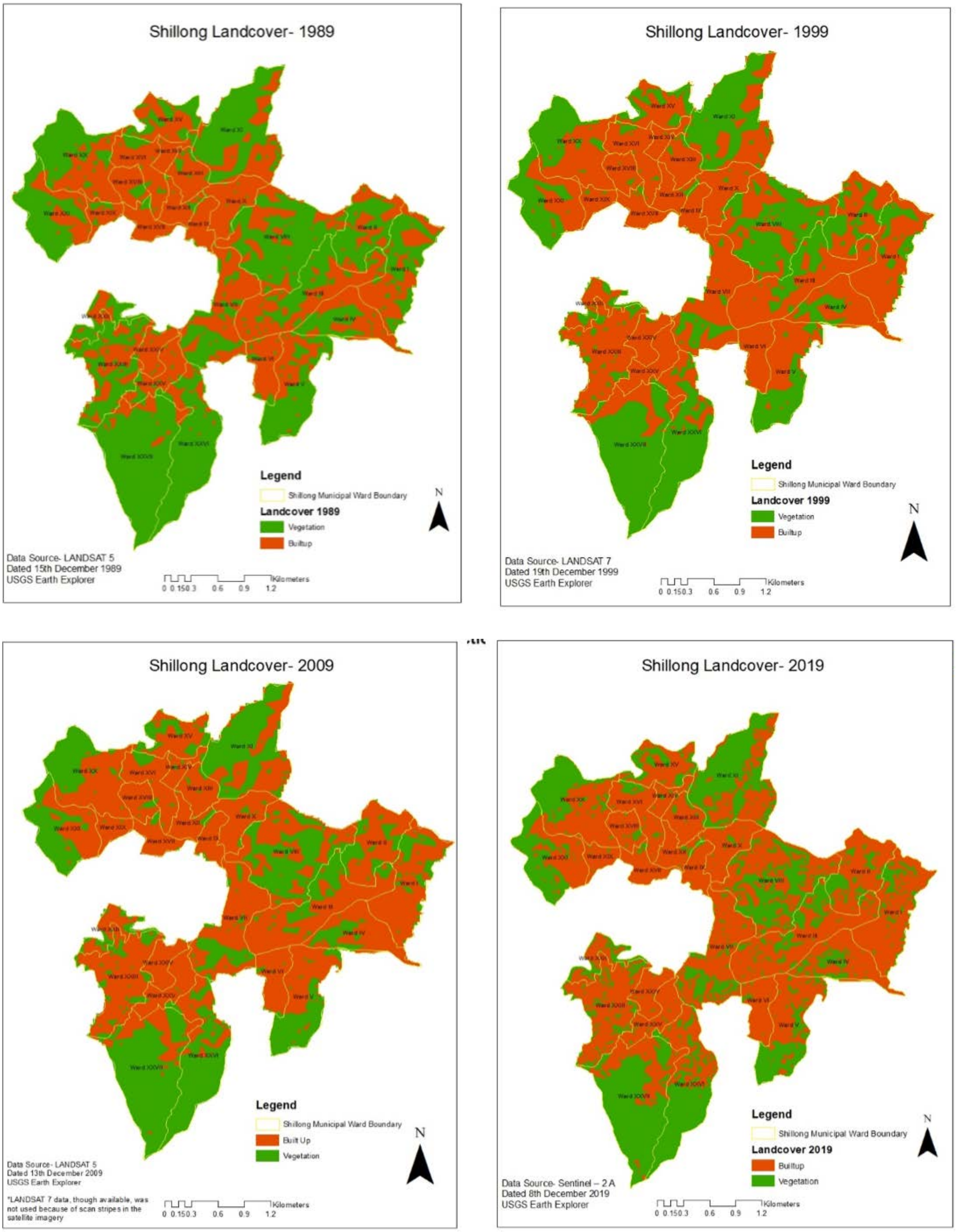


Figure 54: Shillong Landcover 1989,1999,2009 and 2019

Source: IRADe

Taking 1989 as the base year, the built-up area in 1999 increased by a drastic 13%, followed by 1% and 3% in the following decades respectively (Table 6, Figure 7). The analysis shows that the built-up area increased by a significant 17% during the last forty years, taking up the area under the Vegetation cover, which decreased by the same percentage. It can be seen that the Southern and the Eastern part of the city had an increase in the Built-up area, which may suggest the influx of migratory population.

Years	Built-up Area in Sq. KM	Vegetation Area in Sq. KM
2019	6.52	3.67
2009	6.24	3.94
1999	6.15	4.03
1989	4.77	5.41

Table 28: Calculated Built-up and Vegetation areas during 1989-2019 for Shillong

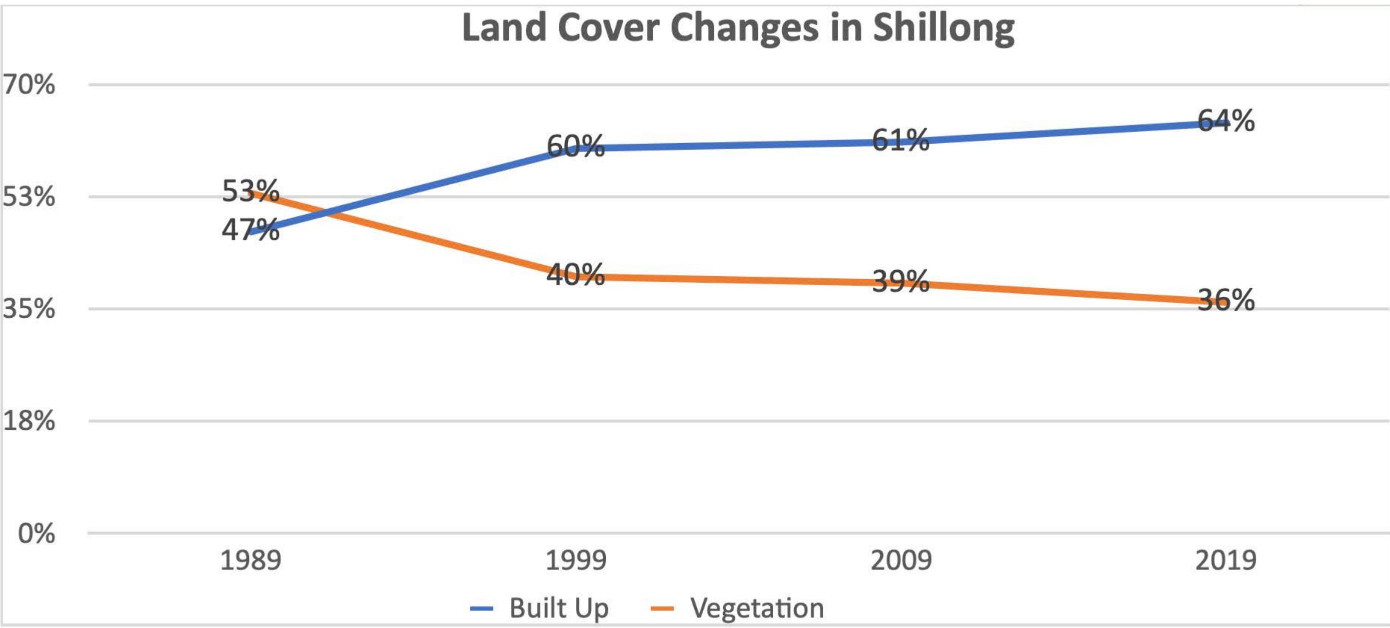


Figure 55: Percentage change of built-up and vegetation area in Shillong (1989-2019)

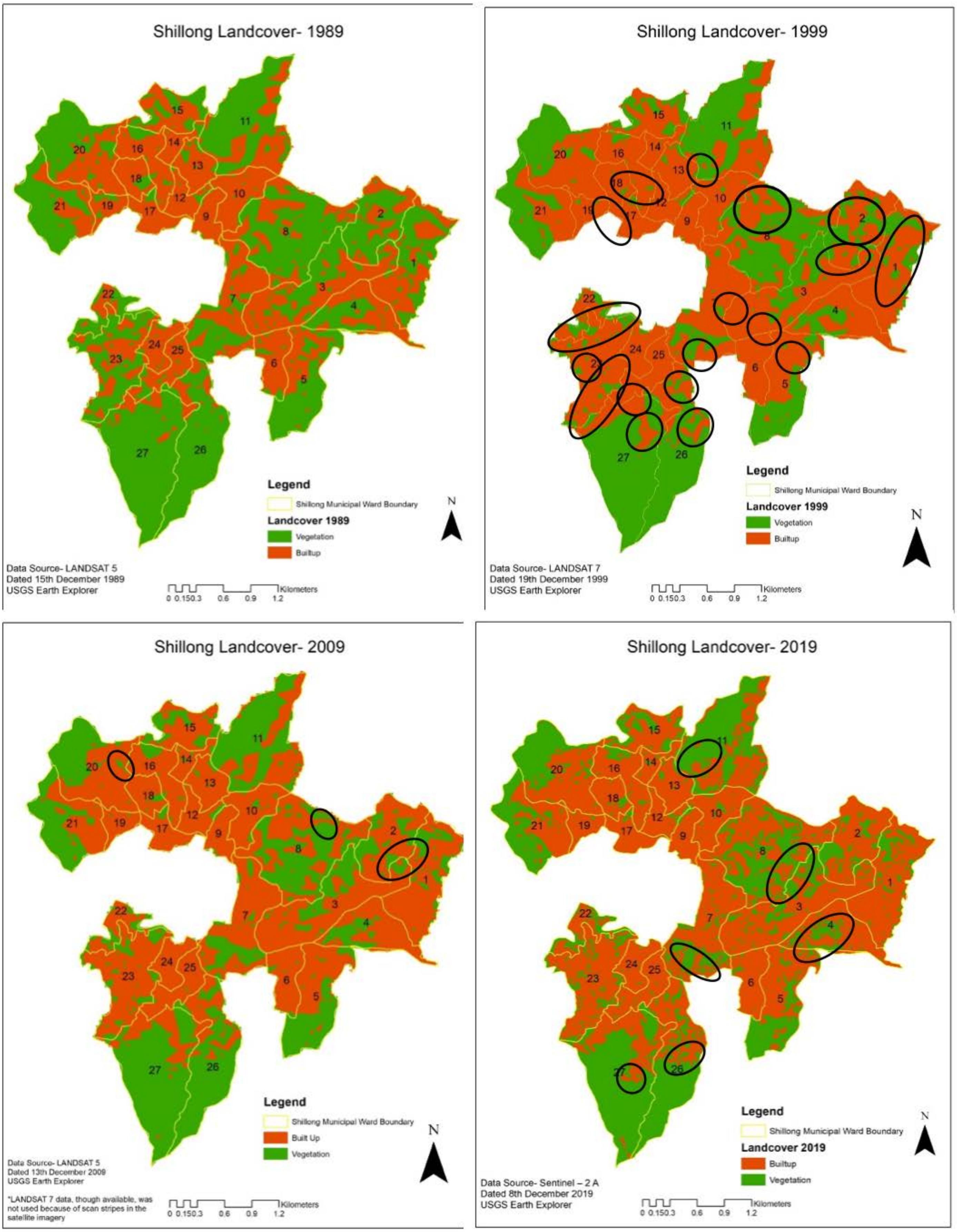


Figure 56: Some highlighted Changes in Built-up area over the years

Further, the ward wise built up and vegetation area for 1989, 1999, 2009 and 2019 was also calculated. The increase in the built-up area under each ward can be seen.

Wards	Builtup% increase 1989-1999	Builtup% increase 1999- 2009	Builtup% increase 2009- 2019	Builtup% increase 1989-2019
1	43%	4%	5%	56%
2	64%	15%	5%	97%
3	20%	0%	4%	26%
4	26%	-2%	4%	28%
5	50%	-1%	13%	69%
6	13%	-4%	1%	10%
7	28%	-5%	-1%	21%
8	30%	20%	17%	82%
9	1%	-2%	0%	-1%
10	-2%	-1%	0%	-2%
11	9%	6%	2%	17%
12	4%	-2%	0%	2%
13	5%	2%	-1%	6%
14	8%	-5%	-5%	-3%
15	4%	9%	3%	16%
16	10%	-4%	0%	5%
17	4%	-3%	2%	3%
18	13%	-4%	-3%	5%
19	19%	2%	-3%	17%
20	25%	5%	-4%	26%
21	32%	0%	10%	45%
22	90%	2%	-7%	80%
23	105%	-4%	-2%	93%
24	7%	3%	-2%	8%
25	24%	-1%	-4%	17%
26	113%	5%	47%	228%
27	115%	2%	32%	190%
Average	32%	1%	4%	42%

Table 29: Built-up area increase in Shillong across different wards

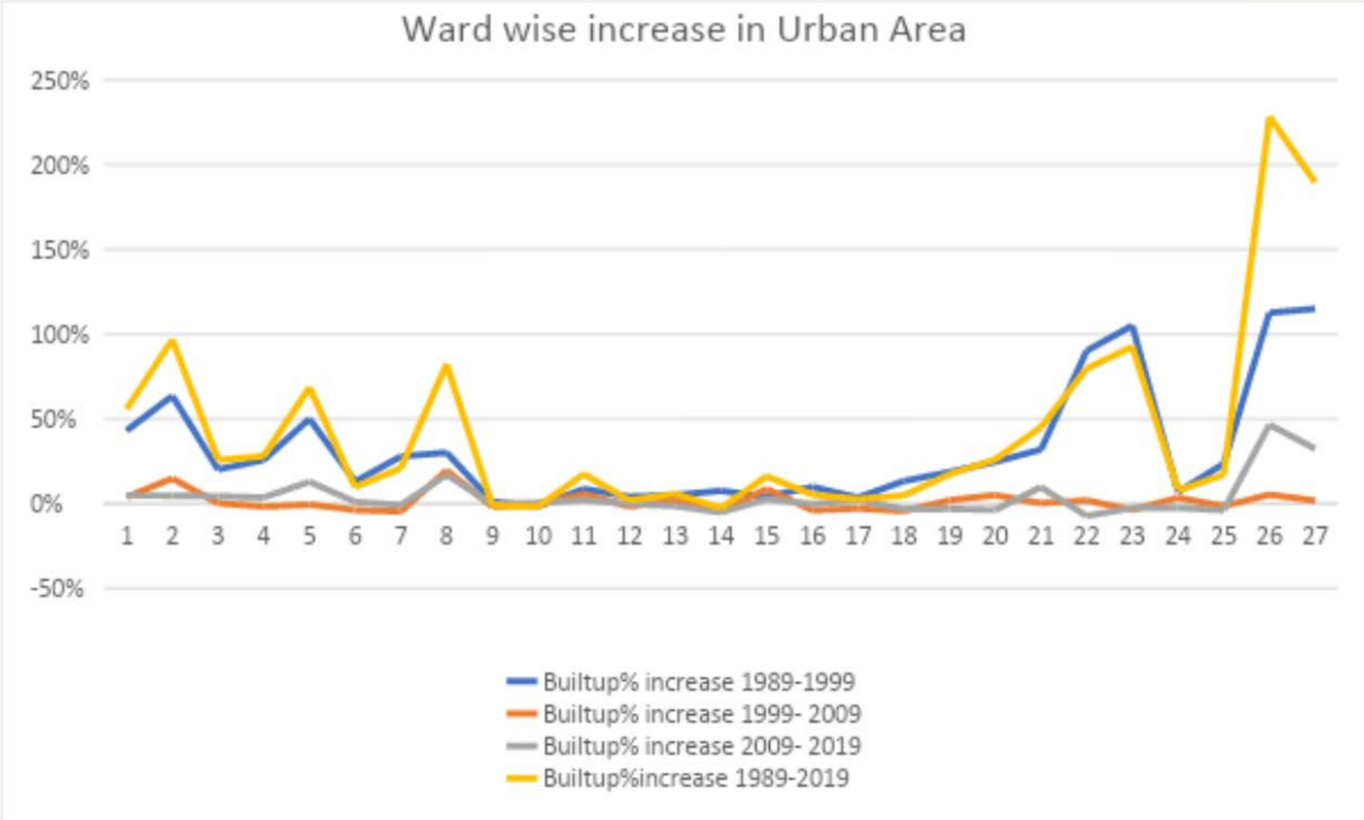


Figure 57: Ward wise increase urban area from 1989-2019

The total increase in the built-up area was categorised for 1989-2019 is shown in Table below.

Increase in Built-up area(1989-2019)	
less than 5 %	Ward no 9,10,12,14,17,18,19
5%-25%	Ward no. 6,7,11,13,15,19,24,25
25%-50%	Ward No. 3,4,20,21
50%-75%	Ward No. 1,5
75%-100%	Ward No. 2,8, 22,23
More than 100%	Ward No. 26, 27

Table 30: Categories of Ward wise change in the built-up area

According to the analysis, Ward no. 1,2,5,8,22,23,26 and 27 have shown more than 50% increase in the built-up area over the last 40 years (Figure 10).

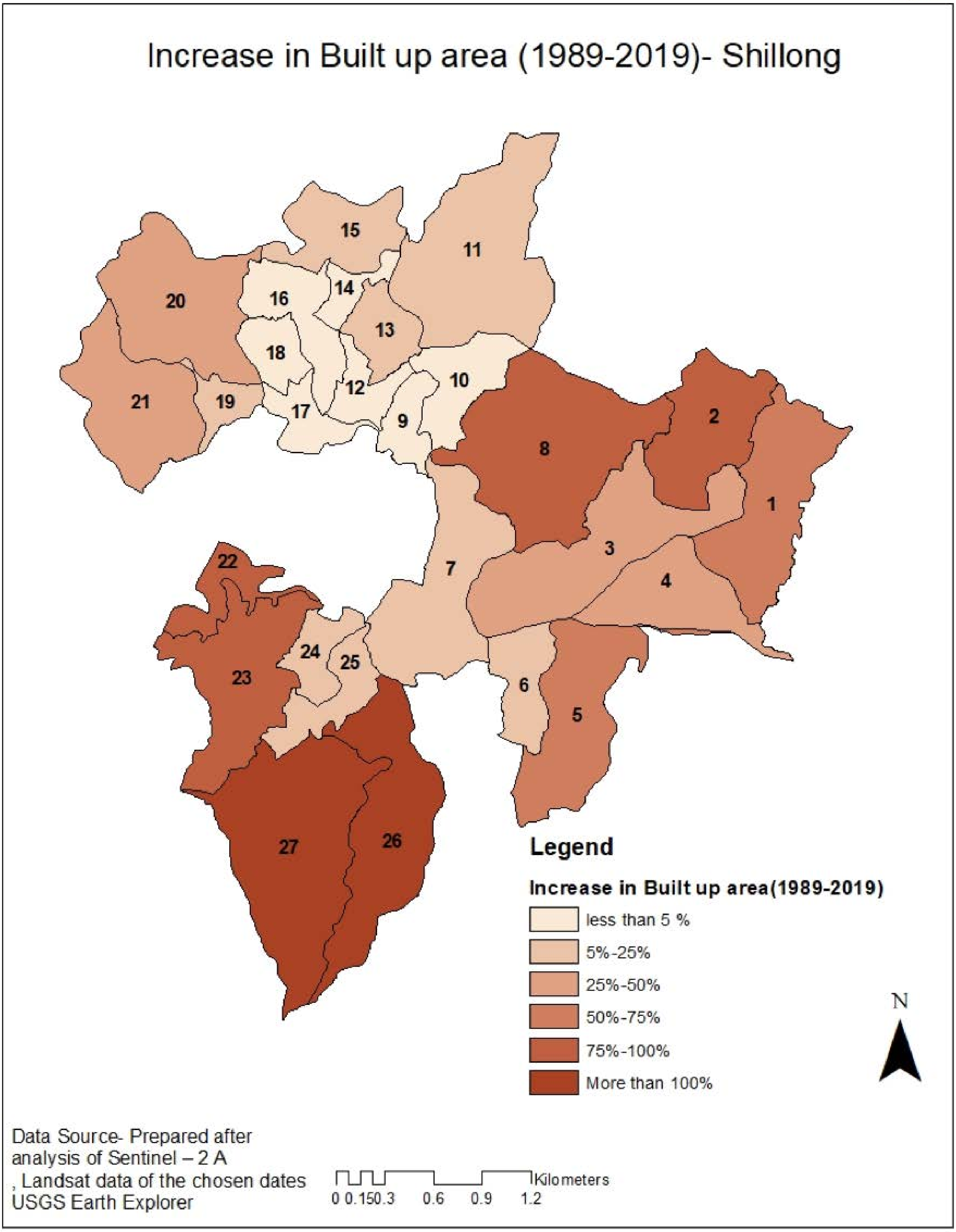


Figure 58: Ward wise increase in Built-up area from 1989-2019

Source: IRADe

Shillong has seen a significant increase in the built-up area over the last three decades. Due to the topographical terrain, the development has been very unplanned, and the pressure on certain parts is more than the others.

This study gives an outline of the Land Cover changes over the three decades. This study needs further examination with better spatial data and on-field validation. An important result of this study was how the LANDSAT and SENTINEL archives could study the land cover changes while also attempting to develop Databa with finer spatial resolutions.

6.2 Urban Planning - Disaster Management Plans

The Government of India, along with the United Nations Development Programme (UNDP), launched the Disaster Risk Reduction Programme (DRR) in 2009 (UNDP, 2019). The Disaster Risk Reduction Programme was implemented in the 3 (three) Districts of Meghalaya, East Khasi Hills, West Garo Hills, and Jaintia Hills. One of the Disaster Risk Reduction Programme components, namely the Urban Risk Reduction Programme, was implemented in the capital city Shillong only.

6.2.1 District Disaster Management Plan, East Khasi Hills District, Shillong, 2019-20

District Disaster Management Authority, Shillong, has developed the District Disaster Management Plan. The document stresses that the East Khasi district is affected by the earthquake and several landslides, storms, flash floods, fire accidents, road accidents, and other hazards. Vulnerability of the district increases due to many factors like increase in population, urbanization, narrow lanes and by-lanes, National Highway 44 passes through the city & mushrooming of concrete buildings. It emphasises the community, as the community is the first responder to any disaster, the community needs to be empowered for coping with disasters and the need to mobilize their capabilities and capacities for effective Disaster Management.

The document comprises of Hazard, Vulnerability, Capacity & Risk Assessment; Institutional Arrangements, Prevention and Mitigation Measures; Preparedness Measures; Capacity Building and Training Measure; Response & Relief Measures; Reconstruction, Rehabilitation & Recovery Measures, Financial Resources; Procedure & Methodology for Monitoring, Evaluation, Updation and Maintenance of DDMP; Coordination Mechanism for Implementation and Standard Operating Procedures & Checklist.

6.2.2 City Disaster Management Plan, 2018

The City Disaster Management Plan for Shillong Municipal Area was prepared by **NESAC, Umiam for the District Disaster Management Authority (DDMA)**. The plan has been developed as a Multi-Hazard preparedness plan for Shillong City to address the city response to **a Multi-Hazard Disaster Preparedness situation, affecting large areas, causing extensive damage to life, property, and environment** epidemics which may affect a large population. In any case, disaster management requires extensive resources and manpower for containment by remedial action during and after the disaster.

The Plan envisages the roles and responsibilities of various Departments of Meghalaya and required coordination with various other city organisations to carry out action plans of preparedness and response strategies. The CDMP envisages a preparedness plan to receive a warning, and a Standard Operating Procedure (SOP) has been laid out. Th plan has documented ward-wise socio-economic vulnerability to various hazards and calculated potentials losses in the city due to disasters through a composite Hazard Index.

6.2.3 Meghalaya Disaster Management Plan, 2016

Meghalaya Disaster Management Plan, 2016, Vol 1, 2 & 3, prepared by **Meghalaya State Disaster Management Authority, Govt. of Meghalaya,** comprises the state's risk and vulnerability assessment. It emphasizes the preventive and preparedness measures that would be necessary for disaster risk reduction in the state. It highlights the importance of mainstreaming Disaster management concerns into development plans and state-level programmes. The report also encompasses the financial arrangements, timely review and updating of the plans.

Volume 1 provides details on the natural and manmade disasters (industrial hazards) over the decades at the state and district levels. According to the hazard types in preventive measures, nodal agencies and support agencies have been listed down. For example, the Nodal agency for Earthquake hazards is Revenue & DM Dept. The supportive agencies are IMD, MoES, GSI, NDRF, SDRF and armed forces. The volume also marks the climate change impact and adaptive responses of the state, wherein climate change projects depict a warning of about 2oC by 2030, with an annual increase in annual rainfall. Indigenous knowledge and coping strategies have been given due consideration with equal opportunities and participation of local people.

Volume 2 enlists the multi-hazard approach of the DM Plan and describes response management arrangements for the state. Strategic plans, Emergency plans and public, advice had been drafted for individual natural hazards.

Volume 3 mainly deals with the important contact numbers relating to disaster management, available equipment with their locations, Emergency Support Functions and roles of different departments, a list of materials for emergencies, a list of hospitals and an available communication system.

6.2.4 District Disaster Management Plan, East Khasi Hills district, Shillong, 2015

'**District Disaster Management Plan, East Khasi Hills District, Shillong, 2015**' (CITY DISASTER MANAGEMENT PLAN, 2018) was prepared under section 31 of the Disaster Management (DM) Act- 2005. It was developed after consultation with the local authorities and regarding the National Plan & the State Plan. The plan includes Vulnerability and Risk assessment, **HRVA** (Hazard Risk Vulnerability Assessment) **for Shillong city** was initiated with **NESAC, Umiam by the Revenue & Disaster Management Dept. and SDMA**. The plan also includes the Institutional arrangement with the District Crisis Management Group (DCMG), District Hazard Safety Committee, Incident Response System (IRS) and Team (IRT), and District Emergency Operation Centre (DEOC). It focuses on the Prevention & mitigation Measures (structural and non-structural), multi-hazard and specific hazard mitigation actions.

6.2.5 Disaster Management Activities Report

The **Meghalaya SDMA** has also published various reports, like **Disaster Management Activities Report, up to 2015,** which presents a glimpse of the various activities carried out by SDMA in taking up wide-ranging DM activities pertaining to awareness building and sensitization, capacity building as well as preparedness and mitigation measures. The Authority has also published a manual on **Dos and Don'ts on Various Hazards, 2015,** to help acquire people to better manage emergencies encountered during disasters.

6.2.6 State Disaster Management Plan, 2006

The **State Disaster Management Plan** (MSDMA, 2018), Meghalaya, was prepared by the **Revenue & Disaster Management Department, Govt of Meghalaya, in 2006.** The plan assesses the existing vulnerability in the state and the capabilities of the selected organizations that play key roles in promoting and strengthening disaster management activities. It emphasizes the disaster management Arrangements and the Meghalaya Relief Manual for basic guidance relating to disaster management structure. The plan emphasizes mitigation and adaptation (recovery) plans for the state.

6.2.7 Other Initiatives

Global Conference on Disaster Risk Reduction - Major Initiatives in North East Towards Disaster Resilience, November 2015 Shillong (FICCI, 2015)was organized by FICCI, NDMA, PBGRB, CIDM towards Preparedness and Emergency Management of Chemical, Petroleum, Petroleum Products and Natural Gas.

Ms Maitreyee Mukherjee has also prepared two manuals in **Emergency Education in Disaster Management and Gender Mainstreaming in Disaster Management for SDMA,** Meghalaya. The manuals stress the concept of emergency education as a useful tool in restoring normalcy after disasters. It will allow meaningful participation in the recovery, rebuilding and imparting knowledge and skills on various aspects.

CSIR-NEIST Jorhat, in association with the National Disaster Management Authority (NDMA), Government of India implemented the scenario exercise to repeat the M 8.7 Shillong 1897 earthquake to assess the anticipated impact in the NE region NE multi-state preparedness campaign in 2013. The exercise involves estimating probable loss and damage by creating a scientific scenario besides various capacity building programs and Mega Mock Exercise to sensitize earthquake preparedness and mitigation efforts throughout NE India. NDMA had also entrusted, Indian Institute of Public Administration (IIPA) to evaluate the project in 2016 (IndianInstitute of Public Administration, 2016). The evaluation of the project has been carried out for three main activities viz. generating awareness, through rapid visual survey (RVS) training, mass casualty management in schools and hospitals and capacity building of various stakeholders including State and district Level Nodal Officers from State Governments, Public Sector Organizations and all related line departments of all the eight states. Lastly, the multi-state earthquake disaster preparedness assessment and evolving the coordinated response of SDMAs and NDMA.

In **2016, GoI-UNDP** initiated the project **'Implementation of the USAID supported - Developing Resilient Cities through Risk Reduction in the context of Disaster and Climate Change's** Shillong along with five other Indian cities. The project looks forward to reducing disaster risks in the urban areas by enhancing institutional capacities and enabling urban communities to be better prepared with increasing capacities to manage climate risks.

UNDP is also currently working with the Shillong city administrators to assess the existing Early warning systems and Risk Assessments. The study has been carried on at the ward and block level, and formal and informal warning systems have been identified. The team has been working on providing recommendations an upgrade of the existing systems and institutionalising the informal and effective early warning systems.

6.2.8 Conclusion

The review of the existing plans indicates that the Meghalaya Disaster Management Authority and the District Disaster Management Authority have developed and updated Disaster Management Plans for the State of Meghalaya, Districts and city of Shillong over the last decades. The District Disaster Management Plan has been developed by **District Disaster Management Authority, 2006, 2015 and 2019-20.** The City Disaster Management Plan (2018) develops a Multi-Hazard preparedness plan to address a Multi-Hazard Disaster Preparedness response. However, ward-level management plans have not been carried out. The source of geology data is the Geological Survey of India (GSI), which is available at 1:2 million scale.

The exiting plans indicate a need for strengthening the institutional framework and the mechanism for effective data management and coordination amongst the various government departments and institutions. The Action plan attempts to update the existing city-level disaster management plans, data collection mechanism, and coordinated planning process. Along with this, detailed ward level maps at the scale of 1:4000 has been developed for hazard susceptibility (landslides, flash floods and earthquakes) and existing critical infrastructure.
In the following chapters, the Plan develops short, medium, and long term Structural and Non-structural resilience action strategies/measures to mitigate and adapt to the existing physical and socio-economic vulnerability, along with its Implementation framework.

Chapter 7

Urban Basic Infrastructure and Disaster Resilience

7.1 Disaster resilience and Urban Infrastructure

Sudden disasters like - floods, earthquakes, cyclones impose risks upon urban development. During a natural disaster, infrastructure failure interrupts vital services, thereby magnifying the need for well-functioning systems beforehand (Chang 2009). For example, power failures may disrupt water supplies and means of transportation during typhoons. Damaged roads after a strong earthquake can hamper the swift transport of people to safer areas, provision of life-saving medicines and supplies to hospitals, and timely distribution of emergency relief (Intergovernmental Panel on Climate Change [IPCC] 2012). Making infrastructure resilient to natural disasters is a challenge in itself, covering aspects like transport, electricity, water supply and sanitation, and buildings and other structures (ADB, 2013).

Basic and critical urban infrastructure and services provide the basic foundation for a city's economic, social, cultural and environmental dynamics. The urban infrastructure provides a backbone for the functioning of a city. Its preparedness towards disaster resilience is directly dependent on the present status of its physical infrastructure and services. The urban infrastructure is the critical lifeline of social and economic activity, connecting communities, industry and markets with essential services for the operation of daily life

Resilience refers to a system's ability to anticipate, absorb, and recover from a hazardous event in a timely and efficient manner (IPCC 2012).“The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain the essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation(IPCC, 2014)(IPCC. Summary for policymakers. In Climate Change 2014: Impacts, Adaptation, and Vulnerability; Part A Glob)

Infrastructure resilience is the ability to reduce the magnitude and/ or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event.(National Infrastructure Advisory Council, 2010).

(https://www.dhs.gov/xlibrary/assets/niac/niac-a-framework-for-establishing-critical-infrastructure-resilience-goals-2010-10-19.pdf)

Estimates show that $94 trillion in infrastructure investments are required by 2040 to meet the global demand for access to electricity, transportation, telecommunication, and water services. In low- and middle-income countries, direct damage to power generation and transport infrastructure caused by natural hazards amounts to $18 billion per year. Additional household and firm costs amount to $390 billion annually due to infrastructure disruptions. The imperative for disaster resilient infrastructure is also highlighted in the global fora, including within the Quality Infrastructure Investment principles of the 2019 Osaka G20 meeting (GFDRR, 2020).

As per the **Sendai Declaration, 2015, of UNISDRR**, the cities are required to work towards reducing disaster mortality, reducing socio-economic losses due to disasters, reducing damage to critical infrastructure and basic services, and increase the access of the urban local bodies to multi-hazard early warning systems and disaster risk information and assessments.

At the 1st anniversary of the **Coalition for Disaster Resilient Infrastructure (CDRI), UN Climate Action Summit 2019** held in New York City, USA, on September 23, 2019, UN Secretary-General's Special Representative for Disaster Risk Reduction, MamiMizutori, proposed "5 points to consider for investing in new or replacing existing infrastructure…', (UNDRR, 2020)

1. Strengthening Infrastructure regulations
2. Measuring and monitoring The exposure of infrastructure investments to risk with mandatory disaster risks
3. Active engagement and creation of incentives for the private sector to participate in the quest of building sustainable and resilient infrastructure
4. Enhancing Knowledge and Capacity Building

7.2 Service level Benchmark (SLBs)

Municipal services viz. water, wastewater, solid waste, heating, and transport are the basic building blocks of efficient, healthy, and economically vital communities. Although ensuring adequate provision of these services is a critical public sector function, many national and sub-national governments fall short. Quality municipal services support the economic development of municipalities. In contrast, poor service levels, interruptions, low coverage levels, and other problems can undermine the quality of life in municipalities, retard economic growth, and erode trust between citizens and local governments rate of population in urban areas was 31.8%. Municipal services viz. water, wastewater, solid waste, heating, and transport are the basic building blocks of efficient, healthy, and economically vital communities. Although ensuring adequate Municipal services viz., water, wastewater, solid waste, transport are the basic building blocks of efficient, healthy, and economically vital communities. Quality municipal services support the economic development of municipalities, while poor levels of service, interruptions, low coverage levels, and other problems can undermine the quality of life in municipalities, retard economic growth, and erode trust between citizens and local governments (Ministry of housing and urban affairs, 2014).

Service Level Benchmarks can broadly be defined as a minimum set of standard performance parameters that are commonly understood and used by all stakeholders across the country. This has also become the cornerstone of the urban reform agenda being implemented as part of various centrally sponsored schemes such as the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and the Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT).

Investment in infrastructure has not always resulted in commensurate outcomes. There is a need for a shift in focus from infrastructure creation to delivery of service outcomes. Sustained benchmarking can help utilities identify performance gaps and introduce improvements through sharing information and best practices, ultimately resulting in better services to people (Ministry of housing and urban affairs, 2014).

The Handbook of Service Delivery Benchmarking (Ministry of housing and urban affairs, 2014) developed by the Ministry of Urban Development through a consultative process provided a standardized framework for performance monitoring regarding water supply, sewerage, solid waste management services and stormwater drainage. It would enable State level agencies and local level service providers to initiate a process of performance monitoring and evaluation against agreed targets, finally resulting in the achievement of service level benchmarks.

The SLBs seeks to:

1. identify a minimum set of standard performance parameters for the water and sanitation sector that are commonly understood and used by all stakeholders across the country;
2. define a common minimum framework for monitoring and reporting on these indicators; and
3. Set out guidelines on how to operationalize this framework in a phased manner.

Service level performance parameters have been identified for four basic urban services. To assess the urban infrastructure stability, resilience and substantiality to disasters following SLBs benchmarks has been documented. The gaps in the existing services and infrastructure provision help determine the infrastructure vulnerability and help frame possible recommendations.

Indicators	SLB Benchmark	Shillong Status
Water supply		
• Coverage of Water Supply Connections	100%	76.89%
• Per capita availability of water at the consumer's end	135 lpcd	78 LPCD
• Extent of metering of water connections	100%	No info
• Extent of non-revenue water	20%	58%
• Continuity of Water Supply	24*7	No info
• Adequacy of Treatment and Disinfection and Quality of water supplied	100%	100%
• Efficiency in the redressal of customer complaints	80%	No info
• Cost recovery in water supply services	100%	12%
• Efficiency in the collection of water supply related charges	90%	71.3%
Sewage Management		
• Coverage of Toilets	100%	93.86%
• Coverage of Waste sewerage Network Services	100%	0 (No STP)
• Collection Efficiency of Waste Water Network	100%	0
• Adequate wastewater treatment Capacity	100%	0
• Quality of Sewage Treatment	100%	0
• Extent pf reuse and recycling of sewage	20%	0
• Efficiency in the redressal of customer complaints	80%	No info
• Extent of cost recovery in sewage management	100%	No info
• Efficiency in the collection of sewerage charges	90%	No info
Solid Waste Management		
• Household-level coverage of Solid Waste management services	100%	46%
• Efficiency of collection of municipal solid waste	100%	80%
• The extent of segregation of municipal solid waste	100%	0
• The extent of the Municipal solid waste recovered/recycled	80%	0
• The extent of scientific disposal of municipal solid waste	100%	0
• Efficiency in the redressal of customer complaints	80%	No info
• The extent of cost recovery in solid waste management services	100%	No info
• Efficiency in the collection of SWM charges	90%	No info
Stormwater Drainage		
• Coverage of Stormwater Drainage Network	100%	85%
• Incidence of waterlogging/flooding	0%	25%

Table 31: Shillong city Basic Infrastructure Status

7.3 Recommendation

The current status indicated gaps in almost all the city's basic infrastructure sectors, and there remains scope for improvement to make the city disaster resilient.

7.3.1 Water Supply

The city's main source of water is River Umium. The per capita water supply is low at 78 lpcd (Shillong Smart City Proposal), and water connections are not metered, and only 12% of the water services cost is recovered.

Water Supply

Recommendations	Organization/ Agencies	Funding Linkages
• Ensuring water supply connection to all the HHs (76.89 of HHs covered at present) • Encouraging Rainwater harvesting practice in all residential, govt. and commercials buildings • Installing smart metering services at locations required (0% metering) • Upgradation of the capacity of the Water Treatment Plant	• Urban Affairs Dept Govt. of Meghalaya • Shillong Municipal Board • Water Security and PHE Department	• One-half of the project cost under AMRUT – CBUD (grant for cities/towns with a population up to 10 lakh) • PPP mode funding (Private and Public Partnership) • Smart city • MLDAA (ADB) • Users/Citizens

Table 32: Water Supply Recommendations

7.3.2 Sewerage

The city records almost 94% of the HHs having individual & community toilet coverage. However, 0.57% HHs still resort to open defecation. With no sewage treatment plant in the city, all the house sullage (kitchen and bathroom wastewater) drains either into the River Umshyrpi in the south or the Um Khrah in the north.

Sewarage

Recommendations	Organization/ Agencies	Funding Linkages
• Ensuring sewerage connectivity for all HHs (100% sewerage network and collection/ treatment facility to all HHs) • Installation Sewerage Treatment Plants for treatment and recycling of wastewater	• PHE Dept • Shillong Municipal Board	• AMRUT/ CBUD • Smart city

Table 33: Sewerage Recommendations

7.3.3 Solid Waste Management

The city produces around 125 MT of municipal solid waste per day.The major solid waste generation sources are households (56%), markets(23%), hotels & restaurants(7%), construction waste(2%), and street sweeping(7%) (B. S. Mipun, 2015) Presently garbage collected is disposed into the gorges of the trenching ground situated at MAWLAI on Shillong Guwahati Road (Shillong Municipal Board, 2018).

Solid Waste Management

Recommendations	Organization/ Agencies	Funding Linkages
• Provisions for waste-collecting bins at every HHs for proper segregation of waste at home/ source • Installation of public bins at required public places • Increasing public awareness through cleanliness drives and campaigns	• Urban Affairs Dept Govt. of Meghalaya • Shillong Municipal Board • PHED	• Smart City • Swaach Bharat Mission SBM

Table 34 Solid waste management Recommendations

7.3.4 Stormwater Drainage

The drains run for 148.91 km across the city and drain into the Umkhrah and Umshyrpi rivers. The Stormwater drainage network coverage is less than 75% of the city, with the incidence of sewerage mixing in drains is almost 100%.

Stormwater Drainage

Recommendations	Organization/ Agencies	Funding Linkages
• Upgradation of the existing drains • Desilting to avoid flooding during monsoons	• PWD • Shillong Municipal Board	• AMRUT/ CBUD • Smart city • MLDAA (ADB)

Table 35 Stormwater Drainage Recommendations

Apart from the four Urban Basic services listed in the MoUD service level benchmark, the other urban infrastructure and services that need to be monitored and attend to standards for the smooth functioning of the city during disasters are Transport, Power (electricity) and Housing sectors. These sectors have been included under the AMRUT (Ministry of Housing and Urban Affairs, 2015) and Smart city (Smart City Proposal, 2016-17) Funding, apart from the earlier mentioned basic services.

7.3.5 Transportation

Though 356 km of road network runs across the city, NMT has not been stressed upon in the city Comprehensive Mobility Plan (CMP) due to undulating topography & operational constraints. The city has limited public transport facilities with limited parking facilities.

Transportation

Recommendations	Organization/ Agencies	Funding Linkages
• Planning and provision for walking tracks, foot-paths, and streetlights along the major roads • Non-Motorized Transport needs to be stressed on, with multi-level parking facilities • Retrofitting, Repair and maintenance of the staircases that covers the city	• PWD NH Division • PWD Central Division • Meghalaya State Govt. Dept	• AMRUT/ CBUD • Smart city • PPP mode

Table 36 Transportation Recommendations

7.3.6 Power /Electricity

The city records no power shortage; however, there are scheduled outages average of 10min/day. The average electricity consumption in residential areas is 300 units /house/day and in the commercial areas is 450 units /shop/day.

Power /Electricity

Recommendations	Organization/ Agencies	Funding Linkages
• Installation of the underground wiring and removal of transformers to avoid traffic hindrance • Installation of solar panels across public/govt. buildings, streetlights and institutions likewise	• Energy & Power Department • Shillong Municipal Board	• Smart city • (Integrated Power Development Schemes) IPDS • Users

Table 37 Power Recommendations

7.3.7 Housing

The city has limited housing facilities, with almost half of its population living in slums and slum-like conditions. There is limited to no access to basic amenities to the urban poor.

Housing

Recommendations	Organization/ Agencies	Funding Linkages
• Increase in the availability of affordable housing for all sections of the society • Provision of the basic infrastructure and services to the urban poor	• Urban Affairs Dept Govt. of Meghalaya • Shillong Municipal Board	• Users • Pradhan Mantri Awas Yojana • PPP mode

Table 38 Housing Recommendations

7.4 Water Scarcity and Rainwater Harvesting

Over the recent past, Shillong has been experiencing a scarcity of potable water due to heavy rainfall, causing a breakdown in the water- supply lines, damaged pipelines due to rod construction work, landslides likewise.

A 2005 report by NEHU (NEHU, 2005) on the 'State of Water in Shillong' discusses that by March, the city dwellers experience water scarcity as the number of tankers starts making rounds across the city. Poor are the most affected by the water issue, with long ques notices at water collection points and carrying water in small tins. The water scarcity was majorly caused due to the poor distribution systems and the unawareness among the people to conserve water, leakages in water lines.

In 2014 (Meghalaya Basin Development Authority, 2018), The Meghalaya Water Foundation (MWF) organized The Shillong Water Conclave: Water Equity and Sustainability in the Context of North East India at Shillong, which discussed the water scarcity in Shillong city and Mawphlang, the only source of water in Shillong requiring protection. Stone quarrying has had a destructive influence on Shillong. Limited recharge of groundwater and surface water required comprehensive water management policy, requiring water management at local and government levels.

In 2019 (Ishana Agarwalla, 2019), the city experienced a water shortage and the Govt. department, both Municipality and PHE unable to supply sufficient water. There are broken and unrepaired pipelines forcing the people to collect water from the broken part of the pipes. The rampant use of the drilling machines to source water by the citizens in the urban area is another reason for the water bed running low. The growing population of the city and its agglomeration is also added to the depletion of the groundwater and growing shortage.

Keeping in view the water scarcity, rainwater harvesting has become one of the best methods to deal with water crises. With a change in the weather pattern and drying up traditional sources, rainwater harvesting is a simple and effective method to overcome water shortages.

7.5 Rainwater Harvesting

Rainwater is usually harvested in the hilly area for irrigation purposes because of the high annual average rainfall and availability of suitable landscapes. The rainwater harvesting technologies help in the local agricultural production (Zhang et al. 2014). By constructing small water reservoirs in the upstream hilly canyon, rainwater can be harvested to irrigate both hilltop and hillslope areas by pumping and the valley areas by gravity flow (Tariqul Islam, M., Mohabbat Ullah, M., Mostofa Amin, M.G. et al, 2017).

Rainwater harvesting (RWH) is the collection and storage of rain, rather than allowing it to run off.
Rainwater harvesting is one of the simplest and oldest methods of self-supply of water for households, and residential and household-scale projects, usually financed by the user.

On the other hand, in Urban areas, rainwater harvesting and management hold tremendous potential for alleviating storm-water runoff and reducing groundwater consumption. RWH can be implemented everywhere from a single household to community level (SHRESTHA, R.R., 2010), the technology is flexible and adaptable to a very wide variety of conditions. It also provides a good alternative and replacement in times of drought or when the water table drops and wells go dry. (HATUM, T. WORM, J, 2006).

Though the costs of installing modern rainwater harvesting systems, storing, and treating rainwater were an area of concern earlier, now, with the advent of new technologies, the investment has a positive return. In association with the Central Ground Water Board and a battery of groundwater scientists and experts, the Central Ministry for Drinking Water and Sanitation has also prepared a conceptual document called the 'Master Plan for Artificial Recharge to Ground Water in India' (NK Realtors, 2018).

There are broadly two ways to harvest rainwater (Rajesh Kumar Gupta, 2015).

1. Surface runoff harvesting: In an urban area, rainwater flows away as surface runoff. This runoff could be caught and used for recharging aquifers by adopting appropriate methods.
2. Surface runoff harvesting: It is a system of catching rainwater where it falls. In rooftop harvesting, the roof becomes the catchments, and the rainwater is collected from the roof of the house/building. This method is less expensive and very effective

Rainwater Harvesting can be useful for the city (Rain water harvesting, n.d.):

- In areas where there is inadequate groundwater supply or surface resources are either lacking or insufficient, rainwater harvesting offers an ideal solution.
- It helps in utilizing the primary source of water and prevent the runoff from going into sewer or storm drains, thereby reducing the load on treatment plants.
- Reduces urban flooding.
- Recharging water into the aquifers help in improving the quality of existing groundwater through dilution.

There should be an amendment in the urban housing construction guidelines to make rainwater harvesting mandatory for Gangtok.

Rainwater Harvesting models that can be adopted by the city are (megphed, 2012):

7.5.1 Rooftop Harvesting

At the individual household level, this system can be adopted mainly for drinking and daily household works. Here rainwater falling on roofs of houses and other buildings is collected through a system of pipes and semi-circular channels of galvanized iron or PVC and is stored in tanks suitably located on the ground or underground. This system can be seen in the northeastern states of Arunachal Pradesh, Assam, Meghalaya, Manipur and Nagaland.

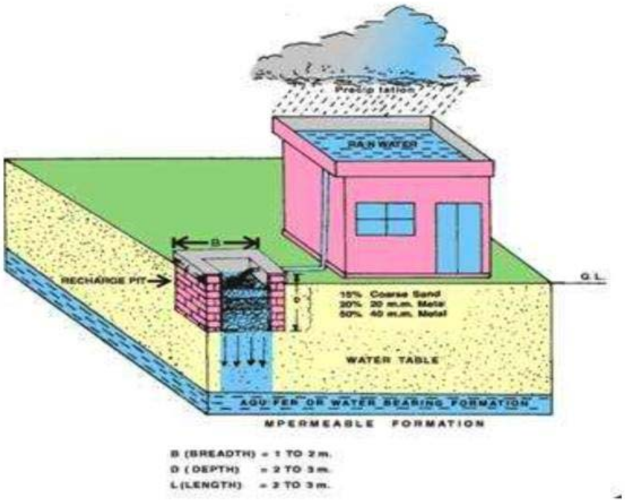
Roof top rain water harvesting in villages of Madhya Pradesh

Figure 60: Roof top Harvesting in Meghalaya, Community & Rural Development,
Source: http://megcnrd.gov.in/gal_iay_pmayg.html

Some of the Roof-top harvesting strategies that can be adopted are (Amit Vashisth, 2019)

- ## Roof Top Rainwater Harvesting Through Recharge Pit

In alluvial zones where porous rocks are uncovered on the land surface or at exceptionally shallow profundity, rooftop downpour water harvesting should be possible through energized pits.



Source: Central Ground Water Board (MINISTRY OF WATER RESOURCES)

Figure 61: Roof top rain water harvesting through recharge pit

- ## Roof Top Rainwater Harvesting Through Recharge Trench

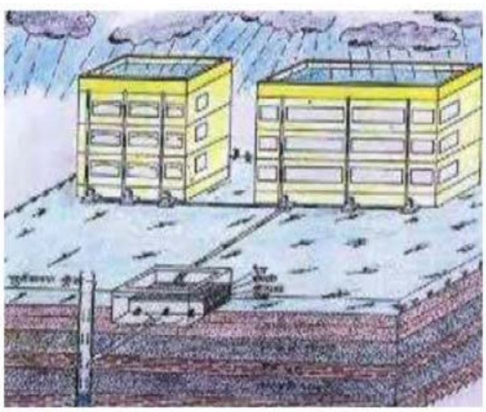
Recharge trenches are appropriate for structures having a rooftop region of 200-300 sq. m. also, where penetrable strata are accessible at shallow profundities.

Source: Central Ground Water Board (MINISTRY OF WATER RESOURCES)

Figure 62: Roof top rain water harvesting through recharge pit

- ## Roof Top Rainwater Harvesting Through Existing Tube wells

In territories where the shallow aquifers have evaporated, and existing tube wells are tapping further aquifer, rooftop to rainwater collecting through existing tubewell can be received to revive the more profound aquifers

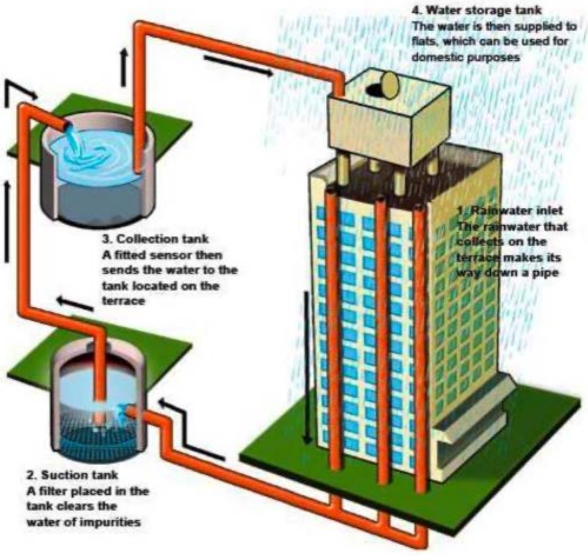


Source: Central Ground Water Board (MINISTRY OF WATER RESOURCES)

Figure 63: Roof top rain water harvesting through existing tube wells

- ## Roof Top Rainwater Harvesting Through Trench With Recharge Well

In territories where the surface soil is impenetrable and extensive amounts of rooftop water or surface spillover is accessible inside an exceptionally brief time of overwhelming precipitation, the utilization of channel/pits is made to store the water in a channel media and along these lines recharge to groundwater through uniquely developed recharge wells.



Source: Diehardindian.com

Figure 64: Roof top rain water harvesting through trench with recharge well

7.5.2 Hill Slope Collection

Practised across Uttaranchal, Himachal Pradesh, Meghalaya, Arunachal Pradesh etc., this system aims in building lined channels across the hill slopes to intercept rainwater. These channels convey water for irrigating terraced agricultural fields. The water is also used to fill small ponds for domestic use and also for the use of cattle.

7.5.3 Springwater Harvesting

Springwater that emerges at the ground surface through cracks and loose joints in rocks under internal pressure of the groundwater system, with no pumping aid, can be harnessed by using split bamboo channels to trap and convey water up to the village/ hamlet for drinking purposes.

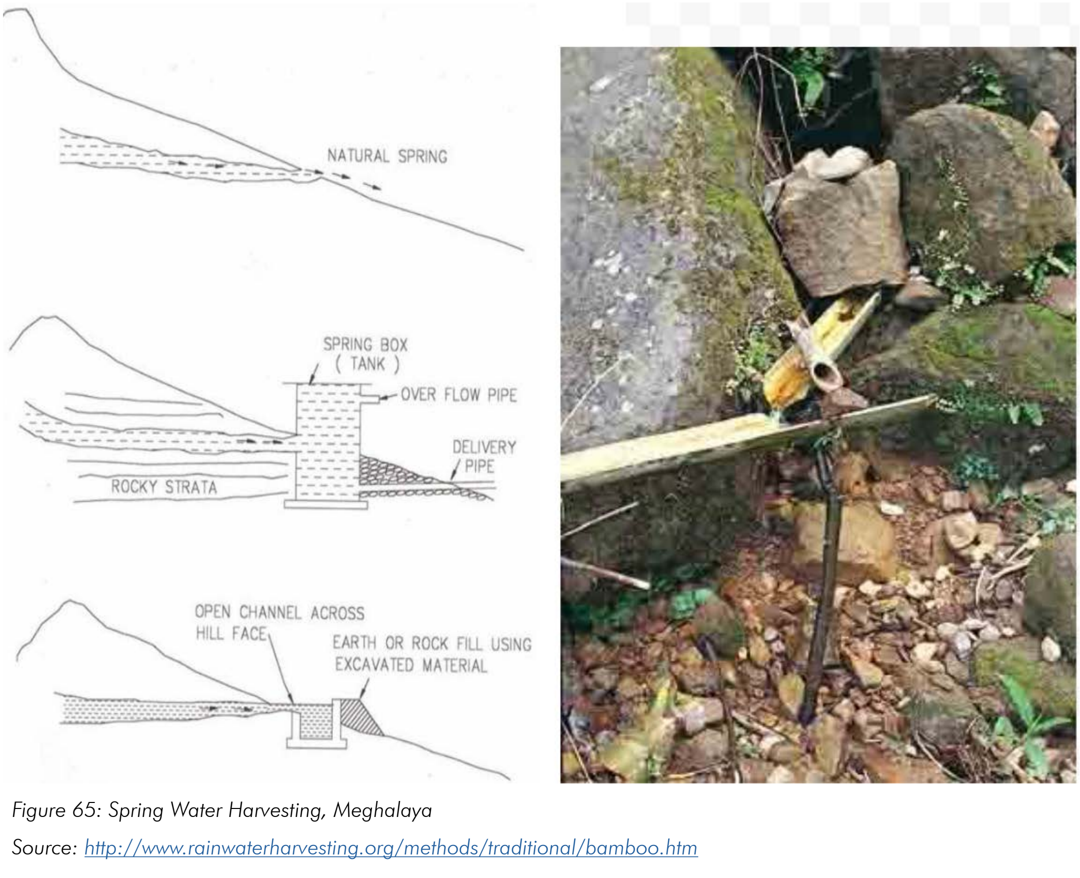


Figure 65: Spring Water Harvesting, Meghalaya

Source: http://www.rainwaterharvesting.org/methods/traditional/bamboo.htm

In the Lahaul and Spiti areas of Himachal Pradesh, water from hill streams is diverted through small excavated channels, called Kuls, for domestic use and irrigation. In the Jammu region, they pronounce it as Kuhals. This practice can also be seen in Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Sikkim and Darjeeling area of West Bengal.

7.5.4 Community Level – Underground reservoir

The underground water conservation system needs to be addressed at a larger community level like Cross – wave. "Cross-Wave" is a water-holding material for rainfall accumulation installed within underground reservoirs. Underground water space created by Cross-Wave effectively controls flood of river and drainage caused by heavy rain. At the same time, it also provides a system through which stored rainwater can be used according to necessity. The reserved water can be used for all purposes such as daily life usage, industrial usage or at the time of emergency.

The important application areas are flood control, rain harvesting, water conservation for life, industry and irrigation, firefighting and any natural disaster. Cities like Jaipur have already installed such systems.

Figure 66: Groundwater Reservoir,, Sekisui Cross Wave Rainwater Harvesting System (https://www.indiamart.com/proddetail/sekisui-cross-wave-rainwater-harvesting-system-3693210291.html)

7.6 Conclusion

Disaster resilience is incomplete without a strong and sustainable infrastructure system in a city. The impact of rising climate events often may translate into a disaster with poor infrastructure services. Coping with inadequate infrastructure on daily basis posts as a challenge; however, climate events directly affect the survival and recovery of the affected. Therefore, it requires a need to upgrade and plan for a disaster-resilient infrastructure. It is observed that the current basic in the city of Shillong is not adequate. Urbanization has created a huge gap between the demand and supply of urban services and infrastructure. The treated direct water supply is available to only 76% of the HHs. Looking into the per capita water supply and availability of potable drinking water and its quality, we find that the city is at risk. The households have access to as low as 78 lpcd of water for daily use and consumption, the standard for a rural settlement. The water treatment plant is not efficient and has exhausted its capacity to accommodate future growth. With the shortage of water rises the need to conserve the same; However, the state has mandated that rooftop rainwater harvesting is mandatory in all buildings. Still, water sustainability is a concerning sector.

Rainwater harvesting in the city is still not at the participatory water management system. The coordinated and coherent approach is missing with the lack of community stakeholder participation in planning and managing the water resource in urban areas. Some of the areas of concern are costing, storage and treatment. Currently, the city has six structures with rainwater harvesting. The central sector scheme has three rooftop rainwater harvesting structures in schools and 3 in State Government Departments (CGWB, 2013). Therefore, there is a need for a more holistic approach to encourage the associations of beneficiaries/ water users to own up the responsibilities to operate, maintain and manage the rainwater harvesting. Other essential infrastructure services such as sewerage where the city lacks a Treatment Plant, and due to unsustainable ways of putting the waste into rivers, at the time of a hazard, the natural water systems often fail and cause flooding in the region. It is also observed that the planned drainage system of the city does not cover even 75% of the area, and the dumping of solid waste often hinders the natural drainage systems such as springs and Johras. This disrupts the natural systems resulting in landslides and urban floods.

Thus, the city's current infrastructure needs to be revisited and further planned to provide disaster-resilient services. The current can barely meet the existing demand. The rise in urbanization and the city's population explosion in the future will affect preparedness and overall disaster resilience. Focusing more on community engagement while looking at initiatives such as rainwater harvesting provides a sustainable solution rather than policy implementation with no incentives. The current natural resources have potential, and a green integration with future infrastructure is a permanent way to prevent building new on the cost of existing systems. The government of India has, over the years, taken initiatives to document and develop manuals to harvest rainwater and recharge the groundwater. A 'Manual on Artificial Recharge of Ground Water', providing detailed guidelines on investigative techniques for selection of sites, planning and design of artificial recharge structures, monitoring and economic evaluation of artificial recharge schemes was brought out by Central Ground Water Board in 1994, updated in 2004 (Central Ground Water Board, 2007) (Central Ground Water Board, 2007).

After the publication of the manual, Central Ground Water Board has brought out five publications on the topic in an attempt to disseminate the experiences gained during various groundwater augmentation projects implemented by the Board in the country. They are:

1) Manual on Artificial Recharge of Ground Water (1994).
2) National Perspective Plan for Recharge to Ground Water by Utilising Surplus Monsoon Runoff (1996)
3) Guide on Artificial Recharge to Ground Water (1998)
4) Guide on Artificial Recharge to Ground Water (2000)
5) Master Plan for Artificial Recharge to Ground Water (2002)

Ministry of Water Resource, Central Ground Water Board, GoI, has also p[published a document on Standard Designs for Adoption of Rooftop Rainwater Harvesting in Delhi (Central Ground Water Board) (Central Ground Water Board) and Rainwater Harvesting Techniques To Augment Ground Water, 2003.

Chapter 8

Disaster Management & Stakeholder Role in Disaster Management

8.1 Disaster Management Cycle

Disaster results from the emergence of extraordinary events (hazards) in vulnerable communities so that people cannot overcome the implications of these extraordinary events (Lindell, M. K., 2013). Disaster management primarily seeks to prevent disasters by reducing the likelihood of hazards or overcoming vulnerabilities (Tarhan, C., Aydin, C., & Tecim, V. , 2016). Disaster Risk Management includes all activities, programmes and measures that can be taken up before, during and after a disaster to avoid a disaster, reduce its impact or recover from its losses (Himayatullah Khan et al, 2008).

1 Risk Hazard event

- Hazard: Severity Probability
- Vulnerability: Root cause, Social forces, unsafe conditions

2 Response

- Rescue & Evacuation
- Relief & External Support

3 Recovery

- Long term Recover
- Internal and Reconstruction Process

4 Prevention/ Mitigation

Ongoing process to lessen the severity of Hazard on People & property

5 Preparation

Action prior to Event to activate necessary Resources

Figure 67: Disaster Management Cycle

Source: Woods L.J et al (2013): When Disaster Strikes, Research Gate

Before a disaster (pre-disaster)

Pre-disaster activities that are taken to reduce human and property losses caused by a potential hazard. For example, carrying out awareness campaigns, strengthening the existing weak structures, preparation of disaster management plans at the household and community level. Such risk reduction measures taken under this stage are termed mitigation and preparedness activities.

During a disaster (disaster occurrence)

These include initiatives taken to ensure that the needs and provisions of victims are met, and suffering is minimized. Activities taken under this stage are called emergency response activities.

After a disaster (post-disaster)

These are initiatives taken in response to a disaster with the purpose of achieving early recovery and rehabilitation of affected communities immediately after a disaster strikes. These are called response and recovery activities.

According to) (Warfield, C, 2008)disaster management aims to reduce, or avoid potential losses from hazards, assure prompt and appropriate assistance to victims of disaster, and achieve rapid and effective recovery. The disaster management cycle illustrates the ongoing process by which governments, businesses, and civil society plan to reduce the impact of disasters, react during and immediately following a disaster, and take steps to recover after a disaster has occurred. Appropriate actions at all points in the cycle lead to greater preparedness, better warnings, reduced vulnerability, or disaster prevention during the next iteration of the cycle. The complete disaster management cycle includes shaping public policies and plans that either modify the causes of disasters or mitigate their effects on people, property, and infrastructure.

- **Mitigation -** Minimizing the effects of the disaster. Examples: building codes and zoning; vulnerability analyses; public education.
- **Preparedness -** Planning how to respond. Examples: preparedness plans, emergency exercises/training, warning systems.
- **Response -** Efforts to minimize the hazards created
- **Recovery** – community to temporary housing; grants; medical care.

8.2 Stakeholder Mapping

Disasters occurring locally and effective disaster management systems are essential to mitigating the impact of disasters (Garschagen, M., 2016). The implementation of disaster management can be more effective if each actor understands their role and capacities in every stage of disaster (Erland Danny el at, 2008). The management system needs to involve governments, NGOs, communities, and the private sector (Wilkinson, E., 2012).

In disaster management, the participation of various actors is proven to support disaster planning and implementation. Good collaboration expected will reduce the burden of government, especially from the financial side. Also, by encouraging the function of other actors, especially the community, will be able to build community resilience (Djalante, R et al, 2012)

8.2.1 Roles and responsibilities of various stakeholders in Disaster Management

Identification of the Stakeholders	List of Stakeholders
1. Primary Stakeholders:	
Actors directly affected by the project, either as designated project beneficiaries or as they stand to gain or lose power and privilege, are somehow negatively affected by the project.	• Vulnerable groups, slums dwellers • Women & Children • Residents of Shillong City
2. Key Stakeholders:	
Actors who can use their skills, knowledge, or power to influence a project significantly are termed key stakeholders.	• Residents of Shillong • Meghalaya Administrative Tanning Institute (MATI), Disaster Management Cell • Mining and Geology Department, Govt. of Meghalaya • Planning Department, Govt. of Meghalaya • Revenue and Disaster Management Department, Govt. of Meghalaya • Meghalaya Disaster Management Authority • Forest & Environment Department, Govt. of Meghalaya • Urban Affairs Department, Govt. of Meghalaya • Public Health Engineering Department, Govt. of Meghalaya • Shillong Municipal Board • IMD • GSI • NESAC
3. Veto Players:	
These are the key stakeholders without whose support and participation the targeted results of a project normally cannot be achieved.	• Revenue and Disaster Management Department, Govt. of Meghalaya • Meghalaya Disaster Management Authority • Urban Affairs Department, Govt. of Meghalaya • Shillong Municipal Board • Residents of Shillong city

Red: Private stakeholders   Green: Public stakeholders   Purple: Civil stakeholders

Table 39: Stakeholders' Mapping

8.2.2 Relationship Status between Stakeholders

Relation Status	Relationship
1. Close relationship in terms of information • Residents of Shillong city and the Municipal Board • Revenue & Disaster Management Dept. Govt. of Meghalaya and Meghalaya Disaster Management Authority	• The local residents avail information regarding city developments and disaster preparedness plans from the Urban local bodies • The Land Revenue & Disaster Management Authorities work in close collaboration in both states, and disaster management plans are developed for each district and city level
2. Alliance and cooperation that are formalized contractually or institutionally • Disaster Management Authorities of Shillong and the Shillong Municipal Board • Urban Affairs Deptt. Meghalaya, Meghalaya Urban Development Agency & Shillong Municipal Board	• The DMA provides required guidance and corporates with the urban local bodies during disaster and disaster mitigation • The two-level institutional framework for the city of Shillong has independent charges of operations relating to their agencies and adequate coordination to address emerging issues. • All the departments work in close collaboration in terms of urban development and implementing housing schemes in Shillong. • Both the institutions' work towards trade, employment and industrial development work under the guidance of the State Govt. • SCC acts as a bridge between the business enterprise and the State and is often consulted by the State Government on all developmental issues like ecology, urban development, infrastructure and planning.
3. Tensions, clashes of interest and conflict-laden relationships	• Clashes in interest persist between departments as one developed plan for urban development and sustainability and the other on heavy industrialization of the hills • Heavy emphasis on the development of tourism and industrialization lead to exploitation and damage to natural resources of the fragile mountain ecosystem; here lies the conflict of interests
4. Direct relationships of dominance/ supervision • Meghalaya Disaster Management Authority and Shillong Municipal Board • Meghalaya Disaster Management Authority and NESAC	• The Disaster Management Authority may direct the Municipal Board in terms of disasters management ion the city level. » ULBS will include: Ward Council Members (27) » The Disaster Management Authority may direct the NESAC to develop relevant maps and early warning system mechanisms to mitigate disasters

Table 40: Stakeholders Relation Mapping

Chapter 9

Early Warning Systems & Operational Preparedness

9.1 Early Warning Systems

The concept of Early warning systems evolved about 2- decades back (the 1970s-80s) due to the prolonged famines that occurred in West African cities. During the Second conference on Disaster Reduction in Kobe, Japan, The **Hyogo Framework for Action 2005-2015** was signed by 168 countries. The framework stressed the need for 'identifying, assessing and monitoring disaster risks and enhancing early warning systems.'

> **'The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatens by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss'**

An Early Warning Systems mainly comprises four elements (MINISTRY OF PERSONNEL,GoI) (NIDM, 2018):

Risk Knowledge
—
the hazard, the elements of risk and the vulnerability (socio-economic and physical) associated with the hazard. Systematic collection of and analysis of data

Monitoring & Warning services
—
forecasts regarding rainfall, river level rise, the decision of warning. Continuous monitoring and operative warning system 24 hours a day is required.

Dissemination & Communication
—
warning and information to the people at risk through radio, telephone, household warnings (simple and useful information)

Response Capacity
—
evacuation centres, search & rescue and relief goods. Disaster management plan in priority.

9.1.1 Hazard Specific Early Warning Systems

Landslide Early Warning Systems

There is no particular landslide monitoring and warning system installed in Shillong. They follow the preparedness only and not the early warning systems. Landslides are usually linked to earthquakes and heavy rainfall registered in the state of Meghalaya, and hence specific steps have been undertaken by Meghalaya State Disaster Management Authority (MSDMA, 2018) like:

- Meghalaya Building Bye-Laws were amended and notified.
- Training on Rapid Visual Screening (RVS) conducted for Engineers and Architects. under the NSSP programme
- Safety Audit has been conducted Lifeline Buildings (critical infrastructures) along with Rapid Visual Survey across 400 schools and retrofitting
- Masons training on Safe Construction
- Training of Incident Response System (IRS) in the 11 Districts organised by SDMA and DDMAs for the District Incident Response Teams based on Earthquake Scenario
- Department of Urban Affairs and DDMA, East Khasi Hills, undertook training on safety construction in the localities of Shillong.
- Regular Mock drills conducted at Educational Institutions, commercial places, office premises, Villages based on earthquake scenarios
- The training programme conducted among the People with disabilities in the districts based on earthquake scenarios
- IEC materials like posters, leaflets, stickers were printed and distributed for awareness among the public
- Detailed information regarding Earthquake and Landslides are incorporated in SDMP-2016, Vol -2 Chapter 2 and 5
- Joint training programmes were conducted with NEIGRIMS, NIDM, NDMA, NDRF, UNDP and others for different Disaster Management stakeholders in the state.
- Mention what needs to be included on the early warning

Flood Early Warning Systems

The Flood warning system's purpose will be to alert for possible flood situations in the city and its vicinity at the earliest, with an optimal rainfall methodology developed to predict rainfall from satellite-based weather monitoring and prediction models supported by on-ground data. There is a need for active participation and an integrated work approach among all stakeholders and annual/regular reports and monitoring activities.

The early warning and forecasting can be based on (MINISTRY OF PERSONNEL,GoI) :

- **Meteorological component**: wherein the weather is predicated using models of the atmosphere and computational techniques
- **Hydrological Component**: wherein the peak discharge from rivers and nalas are calculated. This method assumes the rainfall duration is equal to the time of concentration of the drainage area of the basin that produces the peak discharge.

Existing Flood Warning System

The satellite-based Flood Early Warning Systems (FLEWS) (NESAC, 2014) developed by North Eastern Space Applications Centre (NESAC) have successfully predicted nearly 85 per cent of major floods in the states of Assam and other North-East states - Arunachal Pradesh and Meghalaya. The effectiveness of the Flood Early Warning Systems developed by NESAC at Umiam had increased from a modest 25 per cent in 2009 when it was launched to nearly 85 per cent in 2013.
IMD has already established Polarimetric Doppler Weather Radar (DWR) (UNDP, 2019) installed at Cherrapunjee. The DWR was designed and developed by Radar Development Area, ISRO Telemetry Tracking and Command Network (ISTRAC), ISRO and manufactured by Bharat Electronics Limited (BEL), Bengaluru. This is in validation and calibration mode. DWR provides advanced information, enhancing the lead-time so essential for saving lives and property in the event of a natural disaster associated with severe weather. Though the conventional radars can track and predict cyclones, the DWR provides detailed information on a storm's internal wind flow and structure. Thus, the severity of the weather systems can be quantitatively estimated more accurately than ever before, and more precise advance warnings can be generated to save human lives and property. The polarimetric capability of the Radar will significantly improve the accuracy of rainfall estimation leading to accurate and timely flash flood warnings.

The DWR, being the first S-band (operating at 2.7 - 2.9 GHz) dual polarimetric Doppler Weather Radar, can detect Weather phenomena up to 500 km. This system is installed at a place that receives the highest rainfall on Earth; it shall open up tremendous number of research opportunities in monsoon dynamics, Cloud Physics, the impact of orography in the precipitation process, precipitation characterisation, and thunderstorms, hailstorm genesis and evolution. The data from the DWR is also expected to support a host of operational programmers of IMD and NESAC/ISRO. The near-real-time precipitation estimates from the DWR shall improve the Flood Early Warning System (FLEWS), being developed by NESAC for NE states. It will also enable IMD and NESAC to take up operational activities on thunderstorm now-casting and hail now-casting for NE states.

9.1.2 Dissemination of Warning Alerts

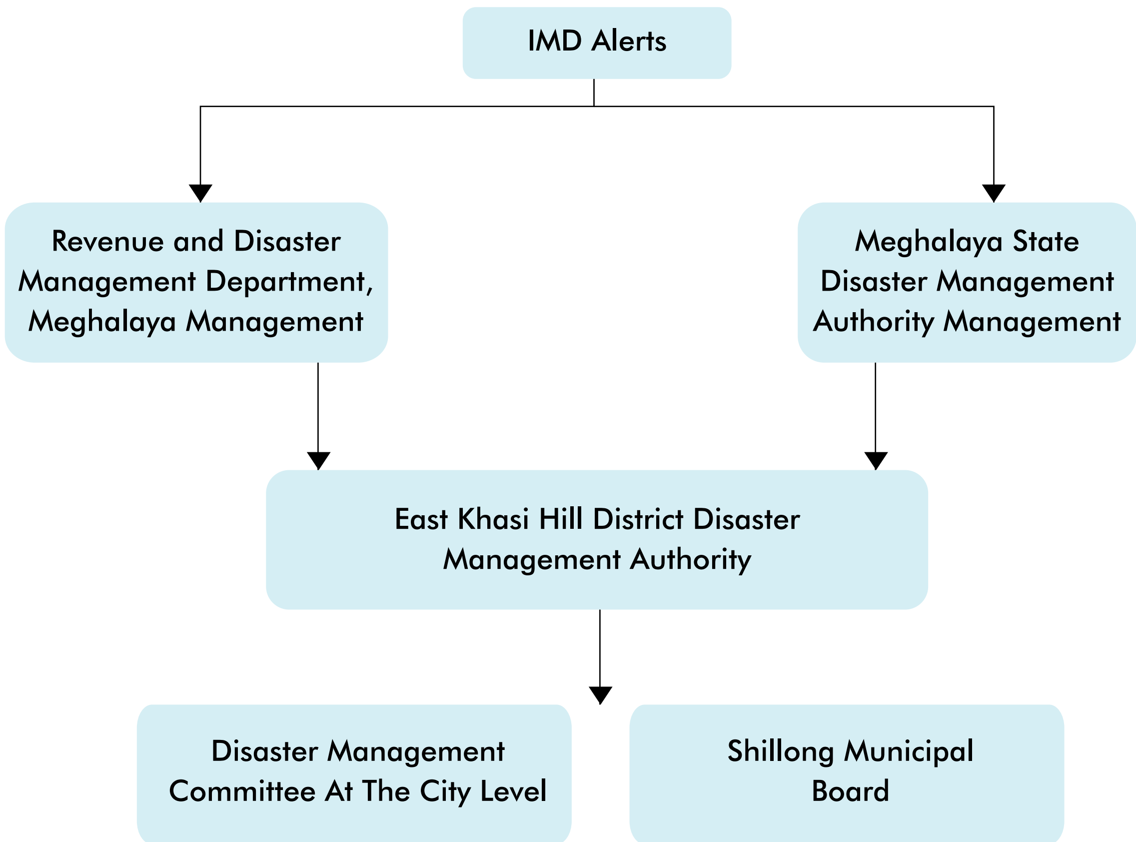


Figure 68: Process for Dissemination of warning alerts

9.2 Operational Preparedness

9.2.1 Inter-departmental Coordination Framework

Indian Meteorological Department

IMD is responsible for monitoring and providing weather forecasts to the city and the state stakeholders. At a Extended Range IMD provides Information on maximum and minimum temperatures for 2 weeks at ten country level and at the city l;evel, provides Maximum and Minimum temperatures for upto 5 days. It also provides furcates for the rainafall, monsoon weather in advance.

With an office in Shillong with Regional Meteorological Center in Guwahati, IMD has established Polarimetric Doppler Weather Radar (DWR) installed at Cherrapunjee. The DWR has been designed and developed by Radar Development Area, ISRO Telemetry Tracking and Command Network (ISTRAC), ISRO and manufactured by Bharat Electronics Limited (BEL), Bengaluru. This is in validation and calibration mode.
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Meghalaya Disaster Management Authority (MSDMA) (SDMA, 2019)

The State Disaster Management Authority, Meghalaya, was established under the Disaster Management Act, 2005 by a Government notification dated 26th June 2008. It is the apex body for disaster management in the State.

The State Executive Committee was also set up to assist the State Disaster Management Authority in its functions.

The District Disaster Management Authorities were also set up for the better management of disasters in the Districts. **Similarly, Block Disaster Management Committees and the Village Disaster Management Committees were set up headed by the respective Block Development Officers and the Village Headmen at the Block and Village levels.** The day to day functioning of the SDMA is looked after by the Executive Officer of the Secretariat, whom the Nodal Officer assists.
The function and responsibilities of the Authority are:

- Framing of Disaster Management Policy
- Preparation of the State Disaster Management Plan,
- Reviewing the preparedness, prevention, mitigation and capacity-building measures in the State.
- Implementation of the preparedness, prevention, mitigation and capacity building programmes in the State.
- Implementation of various awareness and capacity building programmes under the State Plan and the National Disaster Management Authority through the SDMA Secretariat
- Provision of State Disaster Response Fund for management of disasters in the State

Revenue and Disaster Management Department, Meghalaya (Revenue and disaster Management Authority, 2017)

The Revenue Department is a Department that looks after the administration of land and land records in the state. In 2006 Relief and Rehabilitation has been merged with Revenue Department. Similarly, Disaster Management was also merged with Revenue Department and renamed the Revenue and Disaster Management Department.

Revenue Department is to provide relief to the people affected by natural calamities. The Department administers, controls, and maintains the State Calamity Relief Fund, out of which financial assistance and relief are granted to persons affected by natural calamities, such as floods, earthquakes, cyclones, and the new subject of Disaster Management added to the list of functions of the Revenue Department.

East Khasi Hill District Disaster Management Authority

The District Disaster Management Authority has been set up for the better management of disasters in the District under the Chairmanship of the Deputy Commissioner of East Khasi Hills District and Chief Executive Member of the District Council as Co-Chairman with 5 District Officials members. DDMA acts as the planning, coordinating, and implementing body for DM in the District and takes all measures for DM's purposes in accordance with the guidelines laid down by the NDMA and MSDMA. The DDMA prepared the DDMP and continuously monitored the National Policy, the State Policy, the National Plan and the State Plan. The DDMA also ensures that the Guidelines for prevention, mitigation, preparedness, and response measures laid down by NDMA and SDMA are followed by all State Government Departments and the Local Authorities in the District.

District Administration (Shillong city Disaster Management Plan, 2018)

The District Administration has enlisted several precautionary measures to mitigate disasters like the functioning of the Control Room, rain recording and submission of rainfall report, communication of Gauge reading, installation of temporary VHF stations, arrangement for keeping telephone and telegraph lines in order, storage of food, arrangement for keeping drainage clear, agricultural/health/veterinary measures, selection of flood/cyclone shelters, among others, have been adequately planned. The government officials of different departments have been apprised of their duties for pre, during and post-disaster periods. It also is the prime agency responsible for issuing an early warning for all emergencies and natural disasters.

The ULBs, Executive Engineers of Water Resource Department, Executive Engineers of PWD Department, Executive Engineers of PHE, Health, Police, A.H &Veterinary, Joint Director of Supply, among others, have been requested to take all precautionary and preparatory measures and to remain alert to face the challenge of any disaster. The other government officials have also been apprised of their roles and responsibilities to be played during pre-disaster arrangements and during/post-disaster management. Every possible kind of cooperation from all the line departments has been sought for by the District Administration in combating the severe natural calamities that may occur anytime.

Disaster Management Committee at the city level

The City Disaster Management Committee (CDMC) operates with the primary aim to have proper coordination among all the line departments. The Deputy Commissioner is the Chairman of the CDMC, and the city level response is coordinated under his guidance. The City Disaster Management Committee exists to assist the ADC (DM) in:

1. Reviewing the threats of disaster
2. Strengthen Capacity of City Disaster Management Authority
3. Analysing the vulnerability of the city to such disasters
4. Evaluating the preparedness and Response
5. Considering suggestions for the improvement of the City Disaster Management Plan

Shillong Municipal Board

The municipal board responsible for Sanitation and Solid Waste Management: Solid waste management is important for hazard management as the solid waste can choke the drains, leading to urban floods. The state disaster management plan indicates the roles and responsibilities of local governments in disaster management.

Its role in Disaster Management is not clear, along with its responsibilities in providing early warnings that have not been highlighted for Shillong city. The other departments' roles and responsibilities need to be defined to include the Urban Affairs Dept Govt. of Meghalaya, PWD, Water Security and PHE Department, Power and Energy Department and the Roads and NH Departments.

Incident Commander (IC) and Command Staff

The IC is the overall individual in charge of managing on site responses to any incident and is appointed by the RO. He may have a deputy with him, depending upon the magnitude and nature of the incident. For his assistance and management of the incident, there are two sets of staff:
a) Command Staff and b) General Staff. The command staffs comprise IC, Information & Media Officer (IMO), Safety Officer (SO), and the Liaison Officer (LO).

Chapter 10

Traditional Knowledge In Building Disaster Resilience

10.1 Role of Traditional Knowledge in Disaster Risk Reduction

Population across the globe have been living with natural disasters like floods, cyclones, tidal surges, river erosions from time immemorial. They have developed their coping strategies in facing the challenges of the calamities. Indigenous knowledge of the local community practised over time enabled them to withstand the vagaries of nature. Their very survival strategy helped them to save their community when external help was yet to arrive. They continue to nurture such knowledge in their myths, beliefs, and traditions.

Traditional knowledge refers to the undocumented knowledge or oral knowledge which has been passed down from generation to generation to a particular cultural community, in the form of stories, songs, folklore, proverbs, cultural beliefs, rituals, community laws, local languages, culinary recipes and agricultural practicesCITATION Con03 \l 1033 (Connor, 2003) .

Traditional knowledge, holds large amounts of information about the natural world because of its centuries-old experiences and observation of changing natural phenomena CITATION Mer07 \l 1033 (Mercer, 2007)

Despite advancements in knowledge and technology today, such as satellite coverage and surveillance techniques, vulnerability to and risks from natural hazards have been increasing in developing and developed countries (Deken J, 2007). However, the indigenous and local communities worldwide have prepared, operated, acted and responded to disasters using their indigenous methods and passed them on from one generation to the next, even before the invention of high technology-based early warning systems or standard operating procedures for response (UN, 2008). The application of traditional knowledge of indigenous and local communities in Disaster Risk Reduction needs to be explored to bring out the necessary ways to bridge the gap in DRR and pave the future way for developing an integrated framework for DRR.

10.1.1 Traditional Knowledge –Best Practices

Some of the major examples which demonstrate the importance of Traditional knowledge and practices are stated here:

Disaster Adaptation

The local tribes of **Meghalaya believe** in 'U Basa' or goddess dwell among thick and virgin forests. There are 125 **Sacred groves in Meghalaya,** with areas ranging from 0.01 to 900 hectares are unique features of the state. Sacred forests are untouched forests protected by the local people due to their cultural and religious beliefs. They are a treasure trove of rich biodiversity, rich culture and indigenous people. They represent an age-old tradition of environmental conversation based on indigenous knowledge, culture and religious beliefs. In addition, they are a refuge for a large of endemic, endangered and rare taxa. A baseline floristic survey revealed the presence of at least 514 species representing 340 genera and 131 families in these sacred groves (Meghalaya Forest and Environment Department, 2019).

As a part of their cultural beliefs, the **Aka tribe of the Arunachal Pradesh**, India (Gibji Nimasow, 2011)considers the mountain VojoPhu sacred. They believed that if anyone extracts any forest material from the sacred mountain, they will lose their way and will bleed to death. Such belief has helped conserve forest resources in and around the mountain area, which has indirectly helped mitigate various natural disasters like floods, drought, and landslides.

Early Warning

On 26 December 2004, the **Indian Ocean Tsunami** (Syafwina, 2014), the island of Simeulue, which was just 40 km from the earthquake epicentre which caused the 2004 Indian Ocean tsunami, only seven people were reported killed out of 78 000. The oral tradition consisting of stories and songs carrying the messages of the early experience of tsunamis made the local people of Simeulue Island conscious regarding the prediction of tsunamic waves. The oral stories and songs taught people that when an earthquake occurs, they should go to the coast and watch the movement of the tides. If the low tide or retreat of the tide occurs soon after the earthquake, then run towards the higher ground as the low tide will follow up with giant waves.

10.1.2 Nature-based Traditional Knowledge

Nature-based Traditional Knowledge can help mitigate deforestation, store more carbon, hold more biodiversity, and benefit more people, including women, than lands managed by either public or private entities. It can be benefited by (UNEP, 2018).

1. **Increase in climate resiliency** by restoring and protecting ecosystems through nature-based solutions built upon Indigenous knowledge systems that value the inherent worth of ecosystem functions beyond human use/ benefits.
2. **Increased social impact** by utilizing a rights-based approach that ensures equity and human rights for all peoples.
3. **Solutions that go beyond market-based concerns** to include social, cultural and health indicators.
4. **Replicable models of integrated land and water management,** rooted in Indigenous languages that promote and protect human rights, as well as vulnerable plant and animal species through habitat restoration and preservation.

10.2 Traditional Knowledge - Shillong, Meghalaya

10.2.1 Earthquake

Shillong is located in the highest risk zone (V) of earthquake vulnerability in India. The area has witnessed several earthquakes, including the one that occurred in 1897, Jun.12, 16:36 IST (8.7 magnitudes), during which most of the town was destroyed. Some of the buildings that survived the earthquake included traditional houses (B. I. O. Dahunsi & A. K. Mitta, 2008). The physical and structural characteristics of the conventional constructions in Shillong and adjoining areas highlight the inherent earthquake-safe character.

Modern construction risks include many concrete buildings — G+3 stories, without earthquake-resistant features and on landslide-prone slopes are especially vulnerable to collapse. Poor land-use policies and poor construction practices exacerbate the hazards. Extremely high levels of risk have overwhelmed local mitigation capacity despite dedicated efforts by local technical professionals (Sanjoy Hazarika, 2015).

Structural Knowledge in Housing

The only houses being constructed with earthquake resistant technology include traditional and conventional constructions. The vernacular houses are earthquake resistant and constructed on stilts with stable grounds to avoid the risk of landslides. The traditional houses are not just hazard resistant, but also follow the concept of Bioclimatic Architecture.
These houses are made up of locally available materials. The materials used are affordable and easily accessible. The combinations of these materials might differ depending upon the complexity and structural requirement of the area. However, it mainly includes - bamboo, timber, wood, Ikra, thatch, mud, stone and lime mortars. The roofs are of thatch/ straw, while the walls may be from materials such as stone masonry with lime mortars, lime rendered mud walls or thatch depending on prevailing weather conditions. The roofs are made of light materials so that fatalities from failed roofs are limited (WIT, 2017).

Elaborate **procedures are followed in the construction** of such traditional houses:

- Adoption and selection of an appropriate site for construction, keeping in mind the bearing capacity of soil by examining soil texture, moisture content and the other related features.
- Site selection and preparation of the platform for raising the multi-storeyed structure.
- Utilization of locally and abundantly available building material (wood and stone)
- Abundant use of locally available wood and bamboo, within the house too, as they are very light in weight and will cause less destruction during earthquakes
- Similarly, roofs are kept light-weighted and sustained by wood beams; the house is covered by tin sheets

Some of the widely adopted types of houses built using traditional knowledge include:

Khasi Houses

Assam type house or Ikora style

Khasi Houses

The traditional Khasi houses of Shillong and adjoining areas are oval or egg-like shaped, resembling an overturned boat. Khasi homes are built on elevated platforms and have roofs and walls made of stone, lime-rendered mud and thatch. The structure is predominantly composed of timber frames, while the floor is buttressed by limestone or wooden pillars. Usually built on even ground, Khasi dwellings are crafted in a symmetrical, oval shape that helps minimise stress concentrations during earthquakes. Also, this construction style does not involve nails, instead of employing grooves to relieve seismic loads.

Building guidelines:

- Construction of a house on the last hill range is prohibited for safety reasons.
- Two houses are not constructed close to each other. The roof of two houses cannot overlap one another.
- It is not allowed to construct all four walls from stone.
- The timber used for construction, not to be procured from more than a single tree
- Constructing houses on steep slopes near a river is avoided and on triangular-shaped sites
- Houses should be east facing
- Usage of any metal piece is prohibited.

Advantages of Khasi Houses

- Khasi houses indicate that they have inherent earthquake-resistant characteristics due to timber-framed structures.
- Houses are most stable as made with wooden posts and rafters, the roof made of thatch (lighter material) and panel wall in leaves, grass, and reed or split bamboo with or without mud plaster were resistant to earthquake stresses to a great extent.
- The structural framework of the buildings is separated from walls and well tied together while still maintaining good flexibility.
- The roofs are usually made of light materials. Therefore fatalities from the falling roof would be expected to be minimal.
- Placing the buildings on short columns would substantially reduce the effect of lateral loading on them.
- They are symmetrically shaped with negligible sharp corners. The oval shape of the result in the avoidance of stress concentrations at corners.
- The practice of not using nails in house construction, where mortised joints are mainly used.
- Mortised joints increase the energy dissipation of the joints, and it allows the structure to deform and redistribute the lateral loads exerted on the frame.

Figure 69: Khasi Housing

Assam type house or Ikora style

This type of development is often termed the 'Assam type' construction system. A modified and scientifically engineered version of the traditional, vernacular wooden frame and infill construction system was consciously undertaken in the aftermath of the Great Assam (Harsha Sridhar, 2017).

Earthquake of 1897, in Shillong. Almost all the houses of Shillong have been constructed of light materials (wood, ikra, and bamboo with plaster) on earthquake-proof lines, so that despite their location in many cases on steeply sloping hillsides, they were, in the great majority of instances, undamaged) (Sanjoy Hazarika, 2015).
Wooden frame houses with light infill panels constructed using wood from the Khasi pine and
Cryptomeria japonica trees planted earlier on the surrounding hillsides of Shillong, together with locally available materials such as the traditional reeds and bamboo (Anuradha Chaturvedi, 2019).

Building guidelines:

- These buildings are typically built on flat, sloped and hilly terrain.
- They are not to share common walls with adjacent buildings.
- Separated from adjacent buildings, the typical distance from a neighbouring building is 10-15 meters
- As roads in hilly regions are always on ridgelines, the houses rise from low-lying areas along the road until they are accessible from the road.
- The walls are full height Cement Stabilised block masonry. Reinforcement bands run at plinth, sill, lintel and roof springing point levels.

Advantages of Ikora Houses

- Individual units rather than one whole continued building is seismically very effective.
- Seismic resistant structures, as lightweight materials, are used for construction in Assam type construction, unlike in R.C.C. construction.
- These homes follow the C-or L-type plan, using localized materials and are built on 'earthquake-proof lines, despite their location on steeply sloping hillsides.
- Due to its flexible connections and joinery between various elements – posts, wall panels, roof trusses, roofing elements, this system offers good earthquake resistance and performs well in this earthquake-prone region
- The roof is essentially a gable roof form with 30° slopes to ensure greater resistance to strong winds, which this zone experiences
- The house is a rectangular structure preferably laid out in the SW-NW direction. Verandas to be provided on both the short sides.

Figure 70: Assam Housing

10.2.2 Landslides

Landslide is the most commonly occurring hazard in the region (Meghalaya). It takes a massive toll on human lives and leads to substantial economic losses every year besides damages to the environment, resources, infrastructure, and services.

The highways and roads in Shillong-Silchar National Highways face prominent episodes every year (NIDM, 2019). Major incidence of landslides has been reported from urban areas along roadsides and human habitations. The rapid expansion of settlements and non-engineered building construction in the region increases the load on already deteriorated slopes, giving rise to landslides (Kewat Sanjay Kumar et al, 2020). Unplanned inappropriate land-use planning and practices, higher rate development activities, and lack of proper drainage facilities are other prominent factors. The role of vegetal cover in reducing well recognized by the people habituating this region (Rautela P, 2000).

Local Landslide prevention practices

- Bamboo embankments along with wood logs are locally used to control soil erosion and landslides
- Common bamboo species used for this purpose are Melocannabaccifera, Bambusatulda, Bambusabambos, Bambusanutans, Dendrocalamuslongispathus, and Dendrocalamusstrictus
- The traditional practice of home gardening is a vital component in preventing landslides. It has a vital role in soil and water conservation.
- Common tree species found in the home garden are Parkiatimoriana, Sterculiavillosa, Toonacili-ata, Bombax ceiba, Alstoniascholaris, Castanopsisindica, Mesuaferrea, Schimawallichii, Artocarpusheterophyllus, Dilleniaindica, Lagerstroemia speciosa, Psidiumguajava, Tamarindusindica, Oroxylumindicum, Acacia nilotica, Albiziaprocera, Averrhoa carambola, Citrus aurantifolia, Citrus macroptera, Citrus reticulata, Carica papaya, Phyllanthus acidus, Musa species, Magniferaindica, and Persea Americana.
- Khasi houses are not built at the extreme summit of hills to maintain the slope threshold of 30 degrees
- Constructing houses on steep slopes near a river is avoided and on triangular-shaped sites
- Khasi houses raise the plantation cover beneath the constructed house in the form of the bamboo plantation, home gardens, and or tree plantations to reduce the impact of landslides and mass movement of soils and rock
- The locals cultivating lands in the vicinity of streams and rivers chose to settle down at the up sloppy location where the chance of being affected by these disasters was relatively low.

10.2.3 Flash-floods

The state is also very much vulnerable to the impacts of a changing climate and has faced the wrath of freak weather events in the recent past. The state is prone to floods and soil erosion, making the sector much more vulnerable. Cloudbursts resulting to flash floods may lead to loss of life. Around 815,000 hectares in Meghalaya have been affected by soil erosion (GIZ, 2017).

Flash floods have become a regular feature in these areas, mainly due to massive deforestation and unchecked development. The natural springs and water systems are often hindered by haphazard construction and using the drains as a means of dumping grounds.

Local Flash flood prevention practices

- Planting bamboo along ponds and paddy fields prevents soil erosion and stops water from submerging low areas during peak flooding days.
- In preparation for the arrival of monsoon days from December to February, people usually clear the river channels from silt and sand.
- Removed matter (silt and sand) is further used to build bunds along the river and channel. The grass is grown to pad the bund surface and keep the soil from being eroded.
- The method is cost-effective for repairs and maintenance of bunds, reduces siltation during heavy rains and prevents river channels from overflowing.
- House construction includes measures for walls, elevated stores, drinking water and transportation, and divert streams.

10.2.4 Early Warnings (Vanya Jha & Ajeya Jha , 2011)

The communities of this area can recognise warning signs for impending disasters. The new faults appear on the earth's surface and can indicate landslides in the immediate future. Water sprouting in new places can be another indication. Furthermore, a change in the tree's posture at any vertical or horizontal angle may indicate landslides in or around the area. Historically speaking, most of the major landslides in the district have occurred towards the end of the monsoons. When the earth is saturated with water, landslides' trigger is a burst of high-intensity rainfall.

The region does not have a system of traditional early warning documented and hence requires research and reporting.

10.2.5 Traditional Knowledge Transfer

The Community bases Disaster Preparedness are usually traditional coping practices and handy survival mechanisms. The community bases volunteers teams are more effective in disaster preparedness and post-disaster mitigation. Community bases Disaster Preparedness is necessary to empower and enhance capacity building of the vulnerable groups. Encouraging indigenous knowledge through capacity building and training of the officials and representatives of urban local bodies to identify shelters, stockpiling of relief materials, early warning dissemination, and provision of first aids and like-wise.

10.2.5 Traditional knowledge and Disaster Risk Reduction

All traditional knowledge cannot be treated as a DRR tool unless the local community recognises and the knowledge is used for risk reduction (Pribat Rai, 2019). As traditional knowledge holds vast observational data of natural phenomena, it can help modern conventional science understand and analyse natural hazards more precisely. Modern technological data alone will not improve people's lives unless combined with understanding local contexts and needs (Deken 2008).

- Need for proper recognition and utilisation of traditional knowledge by the community (Syafwina 2014).
- Such effective traditional knowledge needs to be documented and captured by using modern techniques. All such practices need to be documented, studied, and innovated to make them more effective and adaptive.
- Need to develop working balance or integration between traditional technology and scientific technology in terms of financial cost of mitigating disasters, as traditional knowledge offers a very cost-effective approach with an environmentally friendly DRR and scientific knowledge method will provide a solid base for the same. (Kelman et al., 2012).
- Need to develop a system for the integration of traditional knowledge into the DRR institutional framework. City-level stakeholders along with the traditional groups can develop such systems using a trans-disciplinary approach for setting a perfect balance for sustainable development and DRR
- Traditional practices with success stories need to be widely popularized by various modern media i. E-print and multimedia booklets in the local language will help to ensure that these principles become a standard practice in disaster mitigation and adaption
- Traditional house construction should also be promoted after being blended with formal prescriptions. The same needs to also be adapted in housing policies (Housing for All 2020) developed by the state government.
- Traditional knowledge and information can be used in making local plans for the region, encouraging participatory planning
- Further research needs to be conducted to enable proper knowledge transfer mechanisms and integrating traditional knowledge with the formal programmes of Government

Chapter 11

Disaster Resilience Action Strategies

11.1 Disaster Action Plan Strategies - Landslide

The city experiences landslide incidences in almost all the wards, usually triggered by heavy rainfall and earthquake movements, causing damage to houses, roads, and sometimes agricultural land. Specific structural and non-structural measures/strategies have been enlisted to mitigate and adapt to the landslides' impact.

11.1.1 Construction (Building Bylaws) and Slope Structural Measures

Short Term Measures (< 3 years)	Governing Institutions. Official
• Amend and update the **Meghalaya Building Bye-Laws 2011 to include** appropriate technologies that should be used in the construction of the slopes and sustainable reconstruction measures • Spatial regulations should control construction activity on slopes above **30° degree** with a maximum of 45° provided appropriate technologies (Ministry of housing and urban affairs, 2014) is employed • Restricting construction of buildings (residential/commercial beyond **15 mts. Height.** • Enforcement of regulations on **indiscriminate quarrying and mining** operations along the slopes	• Architects, planners and civil engineers – • Meghalaya Urban Affairs Department - Shillong Development Authority • Meghalaya Disaster Management Authority
Medium Term Measures (3 -10 years)	
• Adaption of a **cost-effective and sustainable slope retaining engineering** works including the installation of reinforced Gabion retaining walls, hollow concrete blocks, precast stone blocks, concrete blocks, and stabilised soil blocks for slop landscaping (NIDM, 2019) • Unstable slopes need to be **demarcated and re-excavated** to bench them with geonets or bionets or jute matting to promote vegetation growth • Along with the Structural Efficiency certificate, **new construction** also needs to provide better/ improved **multi-hazard disaster mitigation features** adopted into the fabric of the project • **Soil check measures** like seeding with grasses and legumes along the slopes, afforestation through native plants with strong, deep root systems • Adopting **Landscape treatments** such as vertical greening, screen planting and toe planters	

Long Term Measures (About 20 years)

- Research and development in the application of **bioengineering for slope stabilization and protection** Invalid source specified.(use plants in conjunction with more traditional engineering measures and structures to stabilize slopes)
- Identify and assess **Nature-Based Solution (NBS) for landslide Risk ManagementInvalid source specified.**
- Initiate and encourage research in the field of landslide management in the use of green technology, which is clean and affordable technology (both financially and ecologically)

11.1.2 Landslide susceptible zonation

Short Term Measures (< 3 years)

- **Vulnerability and Hazard Risk mapping at the ward level** (ward-wise identification of landslide hazards zones) and updating the same
- Develop and **update Landslide inventory** and its related information (cause, location and impact) on a periodic and regular basis as well as post any landslide occurrence to r**e-assess vulnerable zones and populations**
- Framing **Stakeholders mapping** defining roles and responsibilities of local, city and state-level authorities, organizations and institutions

Medium Term Measures (3 -10 years)

- Develop standard **soil map in line with the stability zonation map** to avoid need-based risk computation in the city
- Relocation and rehabilitation of scattered settlement and encroachments along the banks of river Umkhrah and Umshyrpi, which are prone to flooding and landslide

Long Term Measures (About 20 years)

- Adaptation of the **National Landslide Susceptibility Mapping (NLSM) programme** to aid in prioritising the use of resources (resource management) and framing zoning regulations based on landslide inventories, and prioritise awareness programmes in villages
- **Integrating Slum Evacuation Plan,** for the slums located at the vicinity of landslide-prone areas, into Slum Free Cation Plans /housing for All policy

Governing Institutions. Official

- GSI,
- IMD
- Meghalaya Disaster Management Authority
- NESAC

11.1.3 Land-use and Land Cover Planning

Short Term Measures (< 3 years)	Governing Institutions. Official
• Develop **special permits/ permission for construction on landslide-prone areas** and developing single point clearances points from MDMA • Develop consolidated **Database Management System (DBMS** for effective and efficient planning.	• Meghalaya Disaster Management Authority • Shillong Municipal Board • NESAC • Ward Level Disaster Management Committees • Department of Urban Affairs, Govt. of Meghalaya
Medium Term Measures (3 -10 years)	
• Selection of **dumping sites** not located on or at the vicinity of landslide-prone areas • Critical management of the city drainage by treating cut-slopes and **stabilizing drainage pattern**	
Long Term Measures (About 20 years)	
• Land-use zoning regulation (incorporating landslide susceptibility data) to be made mandatory while **framing land-use policies and land management systems** • Use the hazard zonation maps in regional planning and land use-zoning policy to highlight the landslide-susceptible areas and types of activities allowed in these zones.	

11.1.4 Basic and Critical Infrastructure

Short Term Measures (< 3 years)	Governing Institutions. Official
• **Identification and Vulnerability Assessment** of the lifeline facilities like hospitals and schools (critical infrastructures) and retrofitting the same (if required) • Develop **ward level maps** for basic infrastructure, Critical Infrastructure, Ecological Hotspots, slum pockets & population cover in the city • **Regular maintenance** of the roads and drainage systems across the city	• Shillong Municipal Board • Department of Urban Affairs, Govt. of Meghalaya
Medium Term Measures (3 -10 years)	
• **Systematic investigations** and remedial action to restore and conserve **heritage structures** • Develop integrated **sewerage development plan** and Drainage Master Plan for the city • Provide Storm Water Drainage Network access across all households and a **separate water treatment plant** to filter the sewage before releasing it into the rivers.	

11.1.5 Community Capacity Building

Short Term Measures (< 3 years)

- **Defining role and responsibility** of the Government and local bodies, public sector, NGOs, communities and people at large before, during and after a disaster
- **Training** of first responders in search, rescue and Medicare along with the Communities and Local Bodies (urban planners, architects, engineers, builders, property owners on issues connected to landslide events)

Medium Term Measures (3 -10 years)

- Establish state /district level **Research and Management Cell under "Centre for Landslide Research Studies and Management (CLRSM)"** (NDMA, 2009)
- Increasing **public awareness** for proper land use as well as sustainable land management

Long Term Measures (About 20 years)

- Provision for **research and funding** options for community capacity building

Governing Institutions. Official

- Shillong Municipal Board
- Urban Affairs Department, Govt. of Meghalaya
- Meghalaya Disaster Management Authority

11.1.6 Landslide Early Warning System (EWS)

Short Term Measures (< 3 years)

- **Procure landslide early-warning system** (LEWS) with the help of present state-of-the-art technologies (NIDM, 2019)
- **Monitoring, documentation and projection of rainfall** (amount and intensity (the major cause of landslides)

Medium Term Measures (3 -10 years)

- Install instrumentation and slope **monitoring for a real-time** early warning
- Testing of the response capacities through **Pilot projects**
- Develop and document system for **effective communication** (flow of information) from MDMA to community
- Effective selection of **common mode of information** flow like radio, newspaper, WhatsApp and mobile apps

Long Term Measures (About 20 years)

- **Research and development** in the field of early warning systems, adapting cost-effective and state of the art systems to predict landslides efficiently
- **Engaging and involving stakeholders** including communities in strengthening early warning systems

Governing Institutions. Official

- IMD
- GSI
- NESAC
- Meghalaya Disaster Management Authority
- Department of Land Revenue and Disaster Management

11.2 Disaster Action Plan Strategies - Urban Floods

Flood susceptibility assessment of Shillongcity indicated that almost all the wards are prone and vulnerable to urban flooding during the monsoons and heavy rainfall. Four wards along the southwest of the municipal board (Lower Sichey II, Dara Goan, Tadong and Ranipool being highly susceptible to flooding. This is mainly due to the existence of numerous streams and nallahs across the area.

Some of the measures have been indicated below:

Some of the measures have been indicated below:

11.2.1 Structural Measures (Infrastructure)

Short Term Measures (< 3 years)

- **Strengthen embankments** (cost-effective) or **hydraulic structures** (expensive) along WahUmkhrah, WahUmkhen and Umshyrpi
- **Inspection and cleaning of drainage channels** twice a year (before and after the commencement of monsoons (NDMA, GOI, 2016)
- Develop **ward level maps** for basic infrastructure, Critical Infrastructure, Ecological Hotspots, slum pockets

Medium Term Measures (3 -10 years)

- Develop **channels for diversion of floodwaters** into natural or artificial constructed channels or basin
- **Reconstruct dilapidated and outdated** drainage structures
- **Restrain dumping of solid waste** in streams, causing blocked and increase in the frequency of urban flooding
- Provide access to **Storm Water Drainage Network** across all household

Long Term Measures (About 20 years)

- Research and development in **adopting anti-erosion measures** such as revetments, slope pitching, permeable and impermeable spurs using conventional materials and/or geosynthetics for the protection of towns
- Research and funding options to develop **Water Harvesting mechanisms** at the city and individual household level

Governing Institutions. Official

- Architects, planners and civil engineers –
- Meghalaya Urban Affairs Department - Shillong Development Authority
- Meghalaya Disaster Management Authority

11.2.2 Flood Susceptible Mapping

Short Term Measures (< 3 years)

- **Identify and map Slum located across the flood hazard-prone low-lying areas** of the city at ward level
- Update the **flood-prone area's inventory** after every flood incidence and road-side drainage condition after every rainfall spell
- Document and update reports on the population affected and casualties reported under extreme events, especially the vulnerable population, women, children and elderly
- Develop and update consolidated Database Management

Medium Term Measures (3 -10 years)

- Use **flood hazard mapping** in urban planning and developing **new urban area/urban agglomerations**
- **Regulate the land use** of projected flood-prone areas and reserve only for gardens, parks, playgrounds.
- **Relocate and rehabilitate** settlement and encroachments along the banks of river Umkhrah and Umshyrpi, which are prone to flooding

Governing Institutions. Official

- IMD
- Meghalaya Disaster Management Authority
- NESAC
- Shillong Municipal Board
- Department of Urban Affairs, Govt. of Meghalaya

11.2.3 Community/ Participatory planning

Short Term Measures (< 3 years)

- **Identify and design strategies** to reduce the community vulnerability (social, economic and political) and providing open access to resources to the communities at large
- Encourage **participatory flood-risk mapping** at the community level
- **Public Awareness** campaigns & people participation drills

Medium Term Measures (3 -10 years)

- Implement **indigenous knowledge** (technologies), **coping strategies** and know-how to mitigate disaster
- Develop **temporary shelters and sanitation facilities**

Long Term Measures (About 20 years)

- Research and Development on **mobilizing information and education system** development for the community at large
- Adequate funding in the field of research

Governing Institutions. Official

- Shillong Municipal Board
- Urban Affairs Department, Govt. of Meghalaya
- Meghalaya Disaster Management Authority

11.2.4 Early Warning System

Short Term Measures (< 3 years)

- Monitor and forecast rainfall pattern
- **Update the existing** early warning system with NEAC and MDMA
- **Record and document** rivers and streams inflow between any given reach, during any given duration
- Develop **early warning issuing mechanism** (information flow framework) among stakeholders and community
- Framing **Stakeholders mapping** defining roles and responsibilities of local, city and state-level authorities, organizations, and institutions

Medium Term Measures (3 -10 years)

- Developing **Level Forecasting mechanism** (reliable and cost-effective non-structural flood mitigation measures)[2]
- **Train skilled technical human** resources and adequately allocate Financial resources

Governing Institutions. Official

- IMD
- GSI
- NESAC
- Meghalaya Disaster Management Authority
- Department of Land Revenue and Disaster Management

[2] *https://nidm.gov.in/PDF/trgreports/2018/June/11-15_nidm.pdf*

Chapter 12

Resilience Action Plan Implementation Framework

12.1 Shillong City Disaster Management Plan, 2018

In the purview of the Government of India's defining step towards holistic disaster management by enacting the Disaster Management Act, 2005, the City Disaster Management Plan was drafted for the Shillong Municipal Area, with a vision to make the city safer and disaster resilient.

The Plan provides details of the Emergency Response Plan, a first attempt to follow a multi-hazard approach to bring out all the disasters on a single platform and incorporates the 'culture of quick response'. This also elaborates o. the Activation of Incident Response System, wherein a Responsible Officer would be appointed depending upon the location and degree of disaster. The DC has been designated as the RO in the District. The heads of different departments in the District will have separate roles to play depending on the nature and kind of disaster. The IRS organisation functions through Incident Response Teams (IRTs) in the field. Responsible Officers (ROs) have been designated at the State and District level as overall in charge of the incident response management.

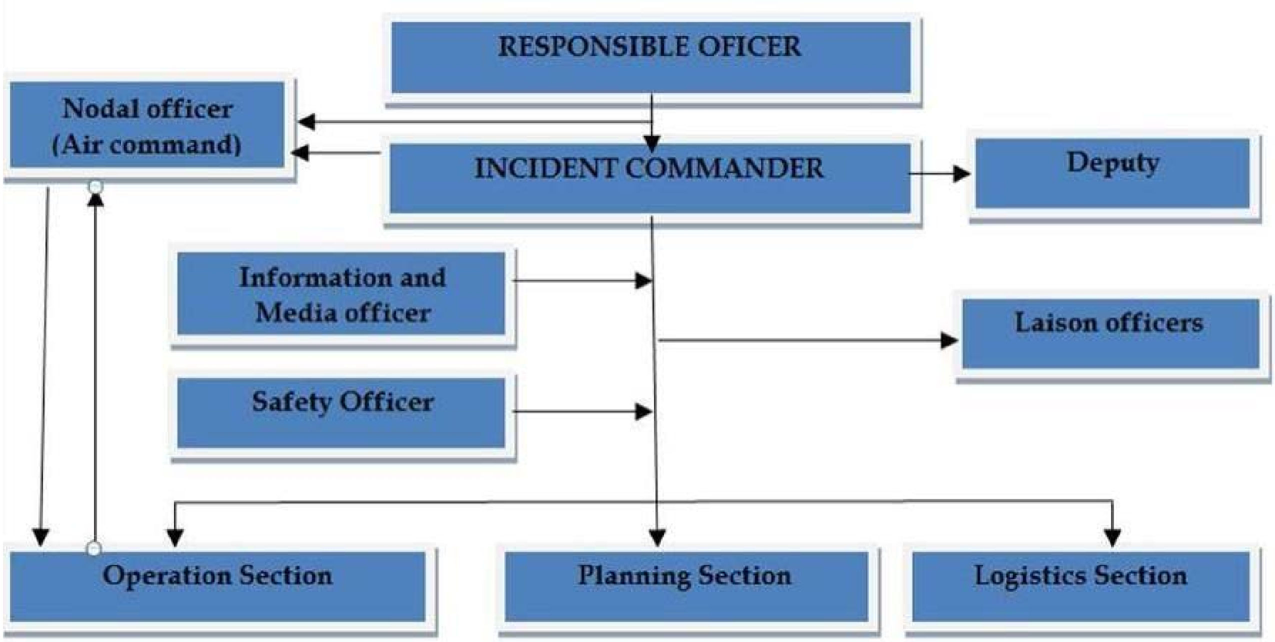


Figure 71: IRS Structure

The Emergency Support Function (ESF) Plan document outlines the objective, scope, organization setup and Standard Operating Procedures (SOPs) for each ESF to be followed by the respective ESF agencies when the Incident commander activates the response plan.

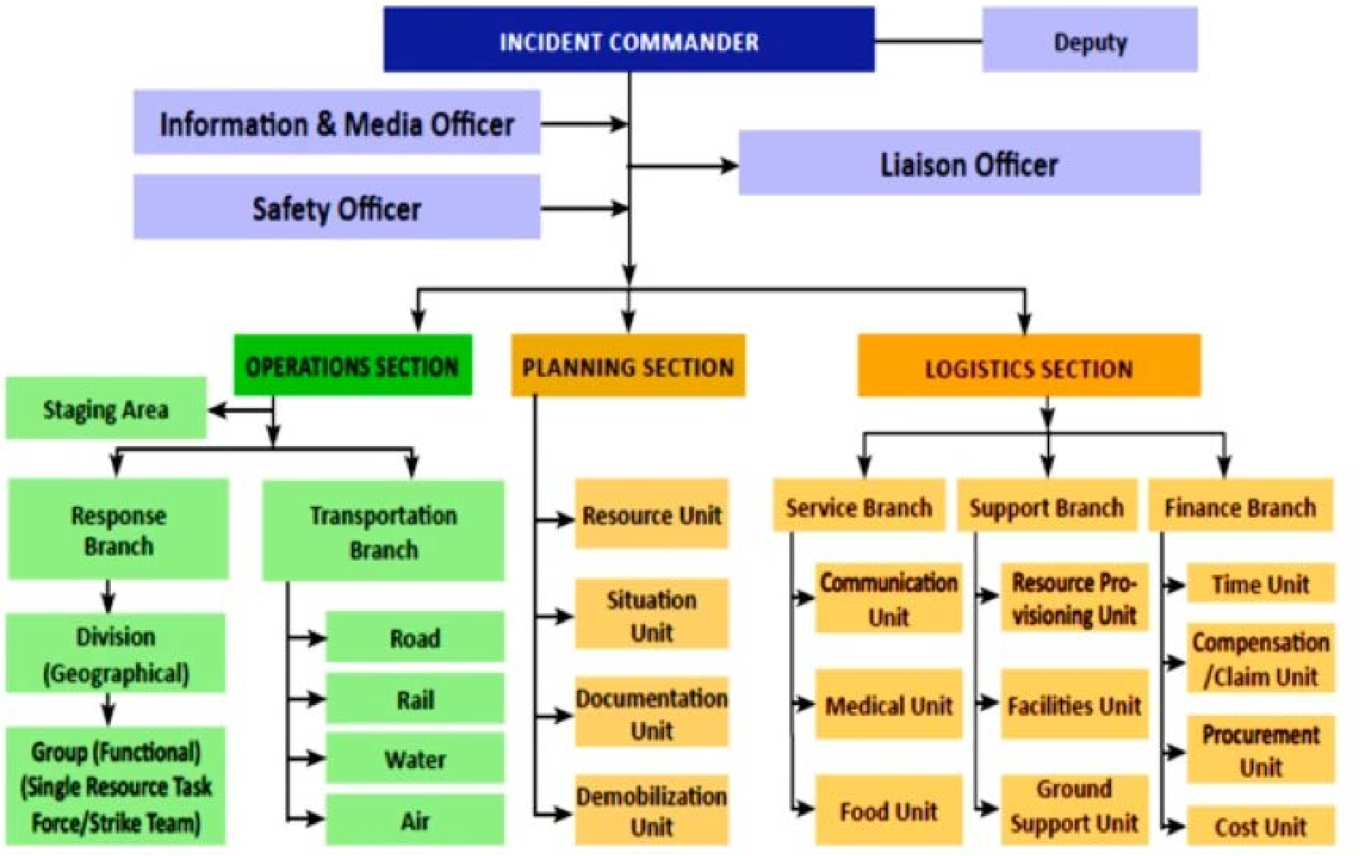


Figure 72: Emergency Support Function (EFS) Plan

12.2 Meghalaya Disaster Management Plan, 2016 (MSDMA, 2016)

The Plan developed by Meghalaya State Disaster Management Authority is divided into 2 Volumes. The first volume provides a general background of the state, with Vulnerability Assessment and Risk Analysis to natural disasters. Whereas Vol. 2 details the Response system and enlists the Role and Responsibilities of the Incident Response System and its team.

The plan defines IRS as an effective mechanism for reducing the scope for ad-hoc measures in response. It provides a participatory, well structured, fail-safe, multi-disciplinary, multi-departmental and systematic approach to guide administrative mechanisms at all levels of the Government. It functions through IRTs in the field. The IRS has two main components; a) Command Staff and b) General Staff.

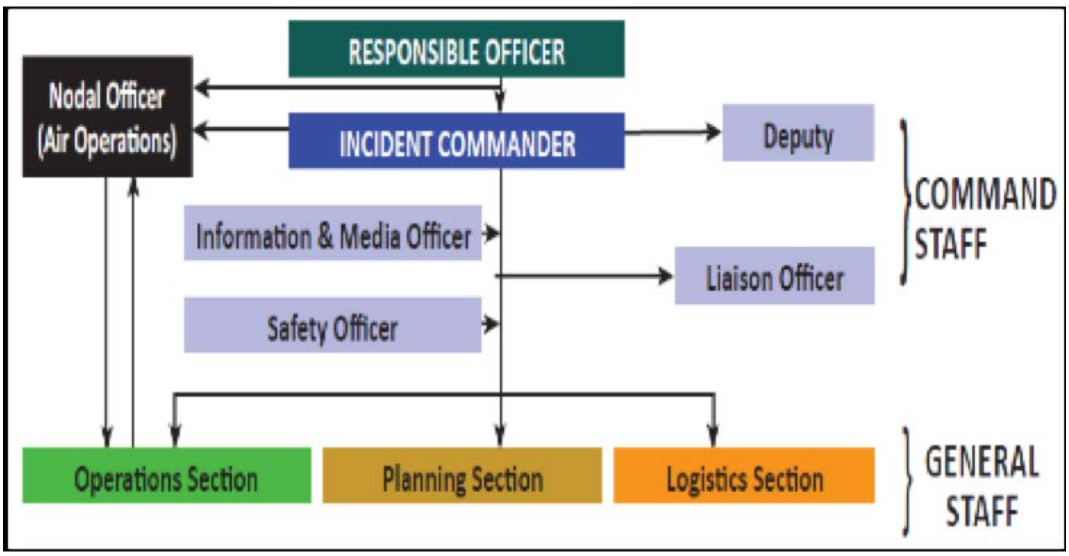


Figure 73: IRS Organization

Planning Section is responsible for collecting, evaluating, and displaying incident information, maintaining and tracking resources, preparing the Incident Action Plan (IAP), and other necessary incident-related documentation.

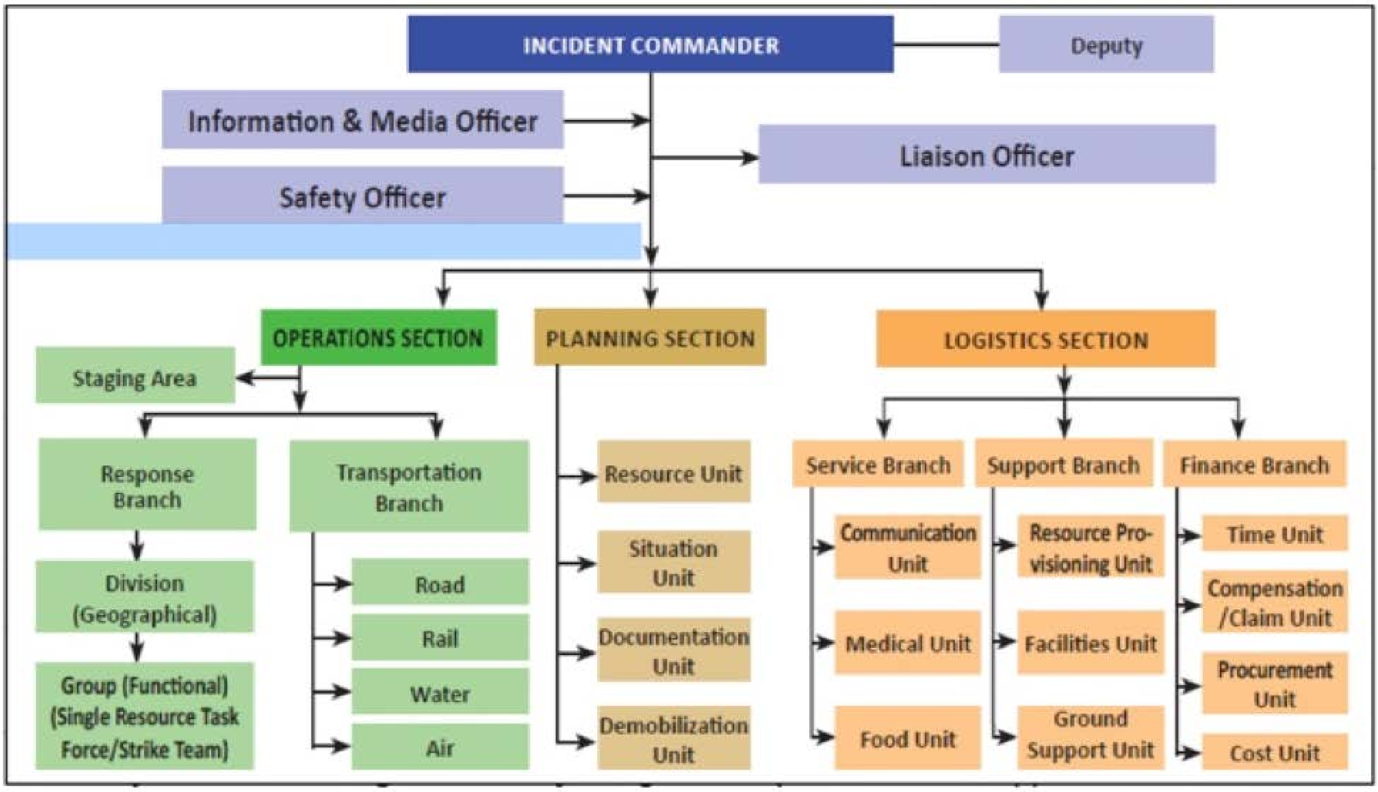


Figure 74:IRT Framework

The disaster specific plans included:

Strategic Plan

Tasks	Nodal Agencies	Coordinating Agencies
Re–framing the building bye–laws based on the relevant BIS (Bureau of Indian Standards) codes and their proper implementation and stricter legislation for the State.	Department Urban Affairs	SDMA
In high–risk areas all buildings should in-corporate earthquake resistant features.		
Public utilities like roads, water supply system, communication network, electricity lines etc. must be earthquake proof to reduce damages to the infrastructures, and alternative arrangement for the same must be developed.	PWD (R) Department of PHE, MeECL, BSNL, PWD (B)	SDMA and DDMA
Advisory for Retrofitting of the weak structures.	Department of Urban Affairs	
Community buildings and other buildings used by large number of people such as schools, dharamshalas, hospitals, Churches etc. must be made earthquake resistant. (Lifeline Buildings)	Department of Urban Affairs & PWD (B)	
Improving educational curricula in technical institutions and technical training in polytechnics and schools to include disaster related topics.	Department of Education	SDMA
Supporting Research & Development in various aspects of disaster mitigation, preparedness and prevention and post disaster management.	SDMA	SDMA
Preparation of literature in local languages with dos and don'ts for the building constructions.		
Getting community involved in the process of disaster mitigation by providing them proper education and awareness.		
Supporting local technical institutions/colleges to conduct and organize research, and organize exhibitions or programs for public awareness.		
Networking of local NGOs working in the area of disaster management.		

Tasks	Nodal Agencies	Coordinating Agencies
Maintenance of law and order.	Department of Home (Police)	SDMA and DDMA
Condoning off severely damaged structures that are likely to collapse during aftershocks.		
Recovery of dead bodies and their disposal.		
Prevention of trespassing, looting etc.		
Evacuation of people from vulnerable built–up areas.	Home Guard and Civil Defence/ SDRF	SDMA and DDMA
Medical care for injured.	Department of Health and Family Welfare	DDMA
Supply of food and drinking water.	Department of PHE/ Department of Food and Civil Supply	DDMA
Temporary shelters like tents, metal sheds etc. [Metal sheds are typically a simple, single-storey structure built with corrugated iron or tin sheets at roof (A) on wooden (timber or bamboo) framed truss (B) supported by wooden (timber or bamboo) or masonry wall or pillars (C) to provide shelter].	Department of Revenue and DM/ PWD (B)	DDMA
Quick assessment of damage and demarcation of damaged areas according to grade of damage.		
Restoring lines of communication and information.	BSNL,MPRO, NESAC, NECTAR	DDMA

Flood Strategic and Emergency Plan

Activities	Nodal Agencies
Take necessary steps to repair/improve the channels to ensure free flow of flood waters.	Department of Water Resource and PWD
Undertake bank protection and anti-erosion works.	
Conduct regular inspection and strengthen flood protection embankment ring and other bunds using modern technology	
Cleaning/desilting of channels/ creeks to be undertaken for improvement of drainage system.	
Improvement of existing reservoirs, tanks etc. through Block Development Office	Department of C&RD
Construct community shelters / buildings at a raised location above higher flood level.	
Flood shelter should be constructed at raised places which at normal times can be used as primary school / ICDS (Integrated Child Development Services) Centre / non–formal education centres / continuing education centres / library.	
Raise the tube well heads.	
Undertake watershed management programmes and encourage rain harvesting technology.	Department of Water Resources
Prevent deforestation on hill slopes/ river catchments area.	Department of Forest
Afforestation of hilly region/flood prone areas is given top priority.	
District wise area specific mitigation plan for flood prone areas should be prepared.	DDMA
Conduct mass awareness programmes covering all the flood prone areas.	
Discourage encroachment on embankment and prevent damaging to the embankment.	PWD
Area flood mapping should be prepared.	NESAC
Establish good communication system in flood prone areas.	MPRO/ Telecom/ DDMA / SDMA

Pre Flood Measures

Emergency Plan	Nodal Agencies	Support Agencies
Formation of a disaster management committee at district level.	SDMA/DDMA	NESAC
Classification of flood prone villages- District wise		
Identification of safe areas- District wise		
Preparation of inventories of rescue and relief materials available and listing them in registers with notice to the owners, especially of rescue items to make them available in an emergency.		
Operationalize control room.		
Liaise with military, BSF, Railway, NGOs, local bodies, electricity and telecommunication authorities. Identify high land for helipad and air dropping of food stuff.		
Strengthening and repair infrastructural facilities including Roads	PWD	
Maintain adequate stock of relief materials.	Department of Food and civil Supplies	
Ensuring sufficient stock of life saving drugs. Vaccines, disinfectants, etc. at appropriate places.	Department of Health and Family welfare	
Formation of action group of trained personnel including doctors and paramedical staff.		
Large scale mapping for delineating natural disaster prone areas.	DDMA / NESAC	
Provide good communication system.	MPRO/ Telecom	
Get the weather forecast, information on release of water from dams.	CWC/ DDMA	DCs/ SDOs/ BDOs can access the information

During the Flood

During the Flood	Nodal Agencies	Support Agencies
Evacuation of people and Cattle which required	DDMA	Department of Veterinary and Animal Husbandry
Conduct search and rescue and evacuation operation.	DC/DDMA	Home Guard and Civil Defence/ SDRF
Ensure availability of food stuff in relief camps.	DC/DDMA	Department of Food and Civil Supplies
Ensure adequate supply of potable water.	DC/DDMA	Department of PHE
Ensure availability of medical facilities like hospital beds, medicine, ORS etc.	DC/DDMA	Dept of Health and Family Welfare

Post Flood Measures

Post Flood measures	Nodal Agencies	Support Agencies
Medical teams should continue their work even after flood water has subsided.	DC/DDMA	Department of Health and Family Welfare
Arrange veterinary aids services and manage cattle in camps when necessary feeds.	DC/DDMA	Department of Veterinary and Animal Husbandry
Arrange for removal of debris and disposal of dead bodies.	DC/DDMA	Municipalities/ Department of Health and Family Welfare
Conduct comprehensive survey of the damage.	DC/DDMA	DDMA
Provide financial assistance for reconstruction of the damaged houses for flood victims	DC/DDMA	Department of Revenue and DM
Provide gratuitous relief to the next of kin of the deceased and provide assistance to the injured.		
Inspect, restore and repair infrastructural facilities.	DC/DDMA	PWD
New construction or reconstruction of natural drainage.		
Disinfect drinking water.	DC/DDMA	Department of PHE
Ensure proper supply of food, essentials, fuel etc. through PDS (Public Distribution System) / fair price shops.	DC/DDMA	Department of Food and civil supplies

Landslides Strategic and Emergency Plan

Strategic Plan

Tasks	Nodal Agencies
Construction of shelters as per BIS norms along landslide prone villages of the District.	Department of C&RD
Up gradation of primary school to serve as shelters having drinking water and toilets.	
Strengthening of embankments, buildings and other basic utility infrastructure in the vulnerable areas.	Department of PWD (B) and Department of Education
Arrangement of strong and reliable communication system in landslide areas.	MPRO
Setting up of control room to monitor the situation.	DDMA
Removal of any dwelling at edge or downstream of landslide prone areas.	
Public awareness programmes should be organized at block and village levels.	
Inform of occurrence of landslide through the public address system and put-up sign boards in the affected areas.	
Special vehicles like JCB excavators, MUV (multi utility vehicles) etc. should be kept ready for use of emergency for clearing the landslide affect the national and state highways and major district roads for easy movement of traffic.	Department of Transport
Medical units with trained personnel should also be kept ready for meeting any emergency.	Department of Health and Family Welfare
Alternative routes should be maintained.	PWD (R)

Emergency Plan

Such disasters are known before its occurrence

After the Landslide

Tasks	Nodal Agencies
Rescue the people who are stranded or otherwise affected.	Home Guard and Civil Defence/ SDRF
Ensure search and rescue operation for the victims and missing persons.	
Restore supply of power and road communication systems.	MeECL/ PWD
Ensure supply of food support to stranded people.	Department of Food and Civil Supplies
Ensure supply of water to stranded people.	Department of PHE
Ensure supply of medical support to stranded people.	Department of Health and Family Welfare
Ensure of traffic in affected area with help of Police Department.	Department of Transport
Ensure proper survey of damage and adequate assistance to be rendered to the victims.	DDMA

District Disaster Management Plan, East Khasi Hills district, Shillong, 2017 (DDMA, 2017)

District Disaster Management Authority, Shillong, has developed the plan. The Plan defines the **Incident Action Plan (IAP)**, wherein the RO/IC needs to take stock of the situation, availability and mobilization of resources to list out the various tasks and provide a proper briefing to the responders. The **incident may be of low, medium or large levels**. The low-level incident would be less than 24 hours, the medium would be more than 24 hours and less than 36 hours, and a large incident would be more than 36 hours of emergency operations. In low or medium-level incidents, an oral action plan may suffice.

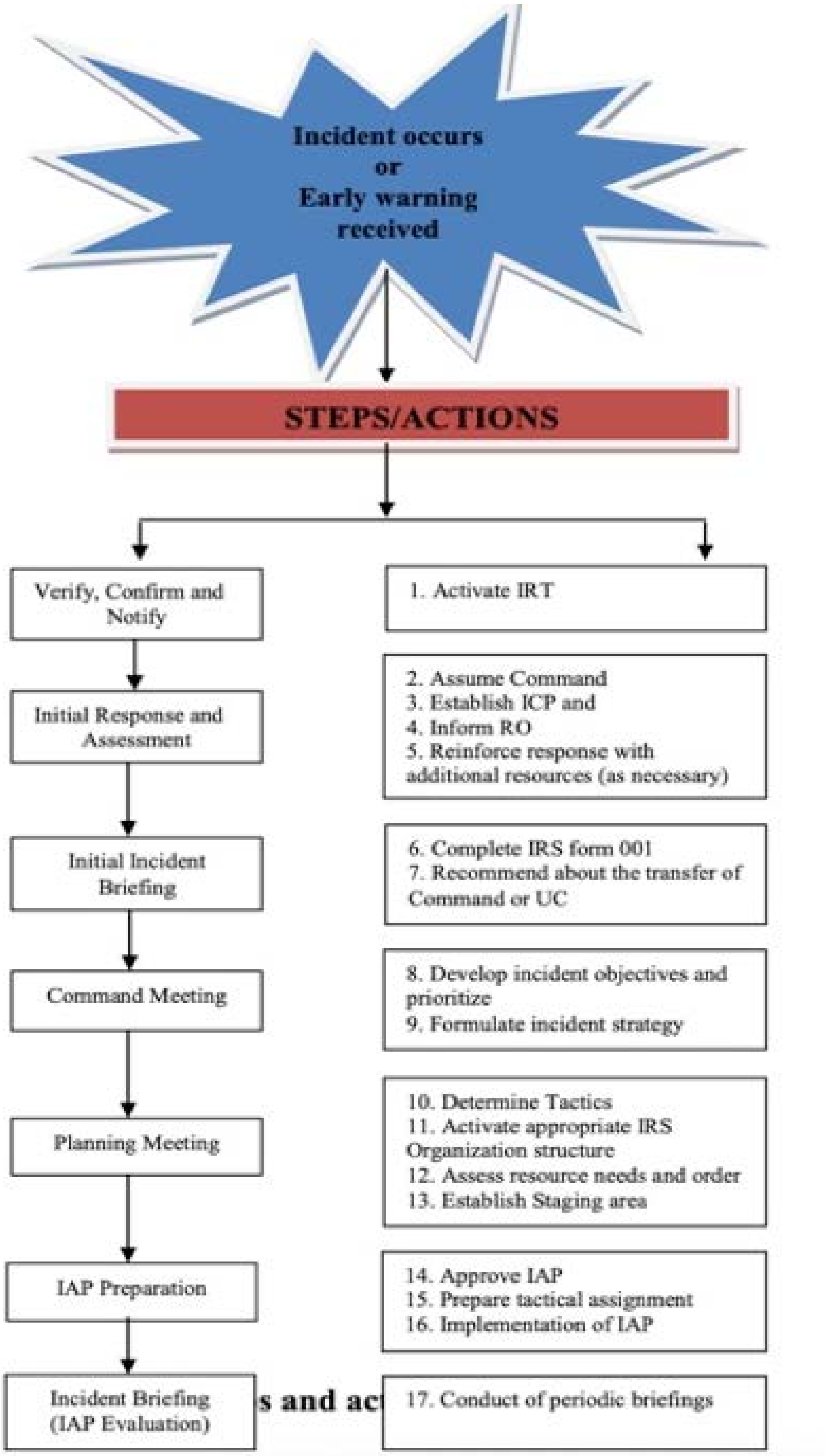


Figure 75: Early Warning Steps and Actions

As a part of the Incidence Response System, the Deputy Commissioner is the head of the district and chairman of the DDMA, is designated as the RO of the district. The DC may delegate some of the functions to the ADC for the day to day supervision and management of the incident. The District Incident Response Team is depicted on the flowchart:

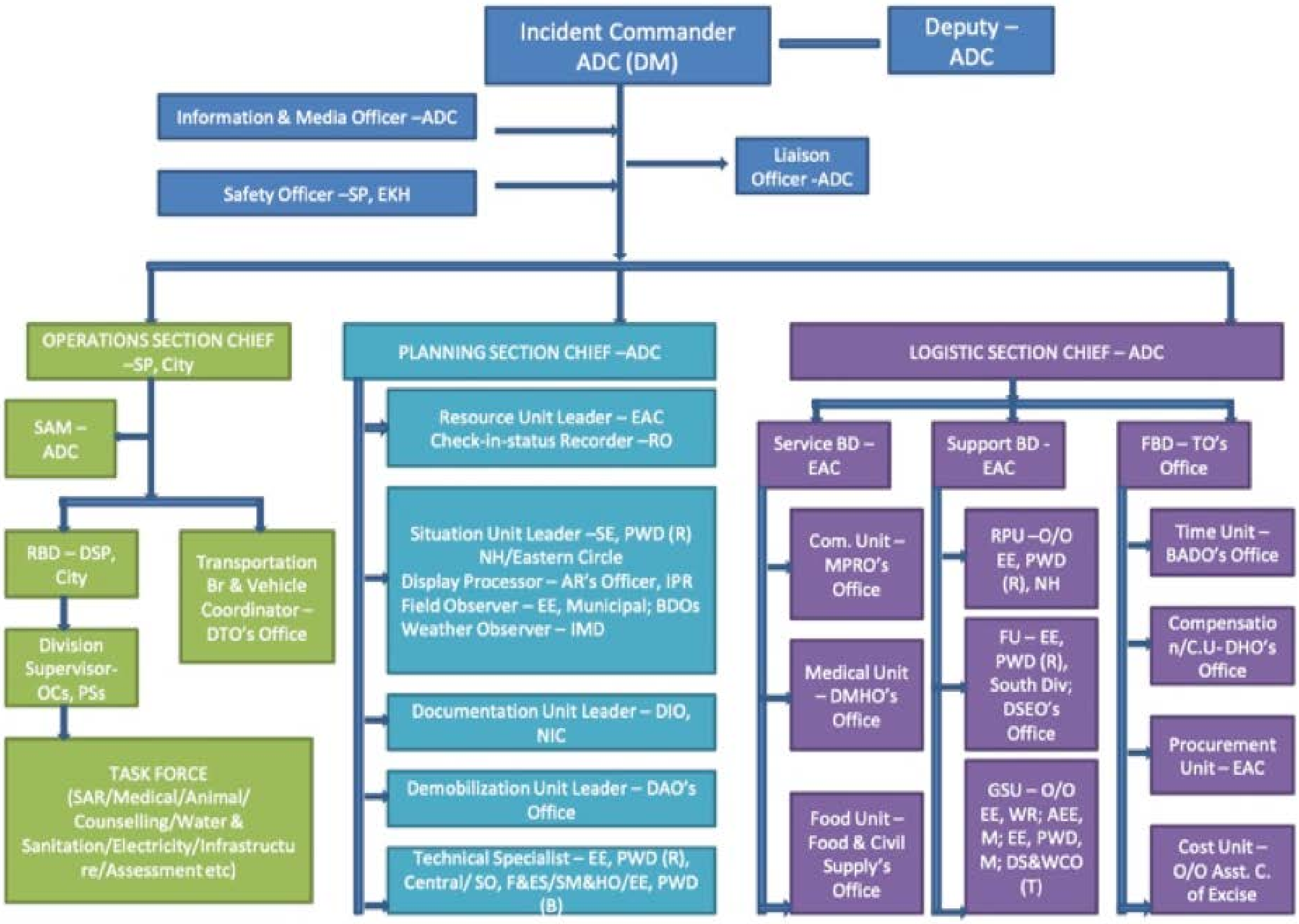


Figure 76: Depiction of Incident Response Team

Responsibility Matrix for Emergency Response Function for certain disasters has been enlisted.`

7.19.1 Earthquake

Time	Task/Activity	Department/Agency
D+15 Min	1. Report the occurrence of earthquake to DDMA, Heads of all line departments, ESF	Officer-in-charge of DEOC
D+30 Min	1. Establish communication links by activating alternate communication equipments i.e. satellite phone, HF/ VHF set, HAM radio, VSAT etc.	DEOC, MPRO, NIC
	2 Deploy mobile emergency communication units to affected areas for establishing communication link	BSNL
	3 Activate the DMTs, QRT, ESFs, IRTs.	DDMA
	4 Ask all Nodal Officers/team leaders and IRT members to immediately report to the EOC.	DEOC
	5 Verify the authentic of the incident from agencies like IMD, block level officers, police and fire department etc.	DEOC
	6 DDMA and EOC together analyze the information and take decision on the level of the disaster (viz. Village level, block level, sub-division level, district level etc.).	DDMA DEOC
	7 Organize first coordination meeting with the ESF team leaders, District IRTs, and the officials from the affected areas. Representative from the affected areas should also be invited to share updates and ground level information. This meeting can be organized in the affected areas (such as Block office) if required and feasible.	DEOC, DDMA
D+1 Hr	1. Establish onsite Emergency Operations Center	DEOC
	2. Activate the emergency response as per the level of the disaster. • In case of disaster up to block level, the BDO takes charge of the emergency response coordination along with the DMTs, QRTs and IRTs. • The BDO shall stay in regular communication with the DDMA and EOC for information updates and response actions. • In case of disaster upto district level, a senior officer of ADC rank shall be given responsibility of emergency response coordination. He/she shall coordinate with the EOC, DMTs, QRT, ESFs etc.	DDMA, DEOC
	3. Activate the search and rescue teams in the affected areas with immediate effect.	DEOC
	4. If required, ask for external support from armed forces, other technical institutions for search, rescue and evacuation operations.	DDMA
	5. Collate and analyse the available initial information on damage and needs.	DEOC
	6. Ask all line departments to share their assessment information with EOC.	DEOC
D+3 Hr	1. Senior ADC level officer to be deputed to the affected areas	DDMA
	2. Assess the condition of roads for quick mobilization of emergency teams and resources to the affected areas and take follow up actions	Transport dept., DEOC
	3. Establish media management/information cell for public information, guidance to volunteers and aid agencies and for rumour control	DEOC, IPR
	4. Contact public and private sector agencies etc. to assist in emergency rescue and relief operations	DDMA
	5. If required, seek assistance from neighbouring districts and state level.	DDMA

	6. Provide security in affected areas and maintain law and order situation	Police dept
	7. Mobilize medical response teams with orthopaedic experts, first aid, cuts, wounds etc. to the affected areas.	Health dept
	8. Mobilize SAR teams and equipments etc. to the affected areas.	DEOC, DDMA
	9. Maintain constant communication with onsite EOC	DEOC
	10. Alert all major hospitals to make necessary arrangements for treatment of injured	DDMA, DEOC
D+12 Hr	1. Open access routes and manage traffic for mobilization of equipment, machinery and volunteers to the affected areas	Transport dept, Police
	2. Establish information centers at strategic places	DDMA
	3. Mobilize relief materials i.e. tents, food materials, water, essential medicines, blankets etc. to the affected areas	DDMA, Supply Dept
	4. Arrange to shift evacuated persons to temporary shelters and ensure provision of food, water & sanitation facilities, blankets, storage of relief materials etc	DDMA, Supply Dept
	5. Set up field hospitals near the affected areas.	Health dept
	6. Arrange to shift injured people to field hospitals.	Health dept
D+24 Hr	1. Develop situation report of the affected areas and share with all stakeholders. This should also be updated on the District website promptly to ensure its availability to other stakeholders.	DEOC
	2. Prepare press note twice a day with details of situation and response being made.	DEOC
	3. Depute additional officers and supporting staff to affected areas from non affected areas	DDMA
	4. Restore essential services i.e. power, water supply, telecommunication facilities of the EOC, HQ, AIR, Doordarshan, offices of key line departments, SP, Hospitals etc. on priority basis.	PHE, BSNL, MeECL
D+48 Hr	1. Plan for a multi sectoral damage and needs assessment of the affected areas. The assessment team may comprise of various ESFs and members from NGOs to have a multi-agency, multi-sectoral assessment.	EOC
	2. Publish the assessment reports and other relevant information on the District website	DEOC
	3. Arrange for identification, photograph, post mortem, and record maintenance for disposal of dead bodies (Refer NDMA guideline on disposal of dead)	Health dept. Police dept.,
	4. Set-up an information center near the relief shelters for community, relatives, NGOs etc.	DEOC, IPR
	5. Arrange system to receive reports and complaints regarding missing people and other such losses and damages, and initiate search in hospitals, shelters and police records	DEOC
D+72 Hr	1. Arrange for disposal of unidentified and unclaimed dead bodies	Police dept., Health dept.
	2. Arrange for transportation of injured people from local hospitals to district hospitals or to other specialized hospitals (if required)	Transport, Health dept
	3. Initiate relief distribution and recovery actions	DDMA

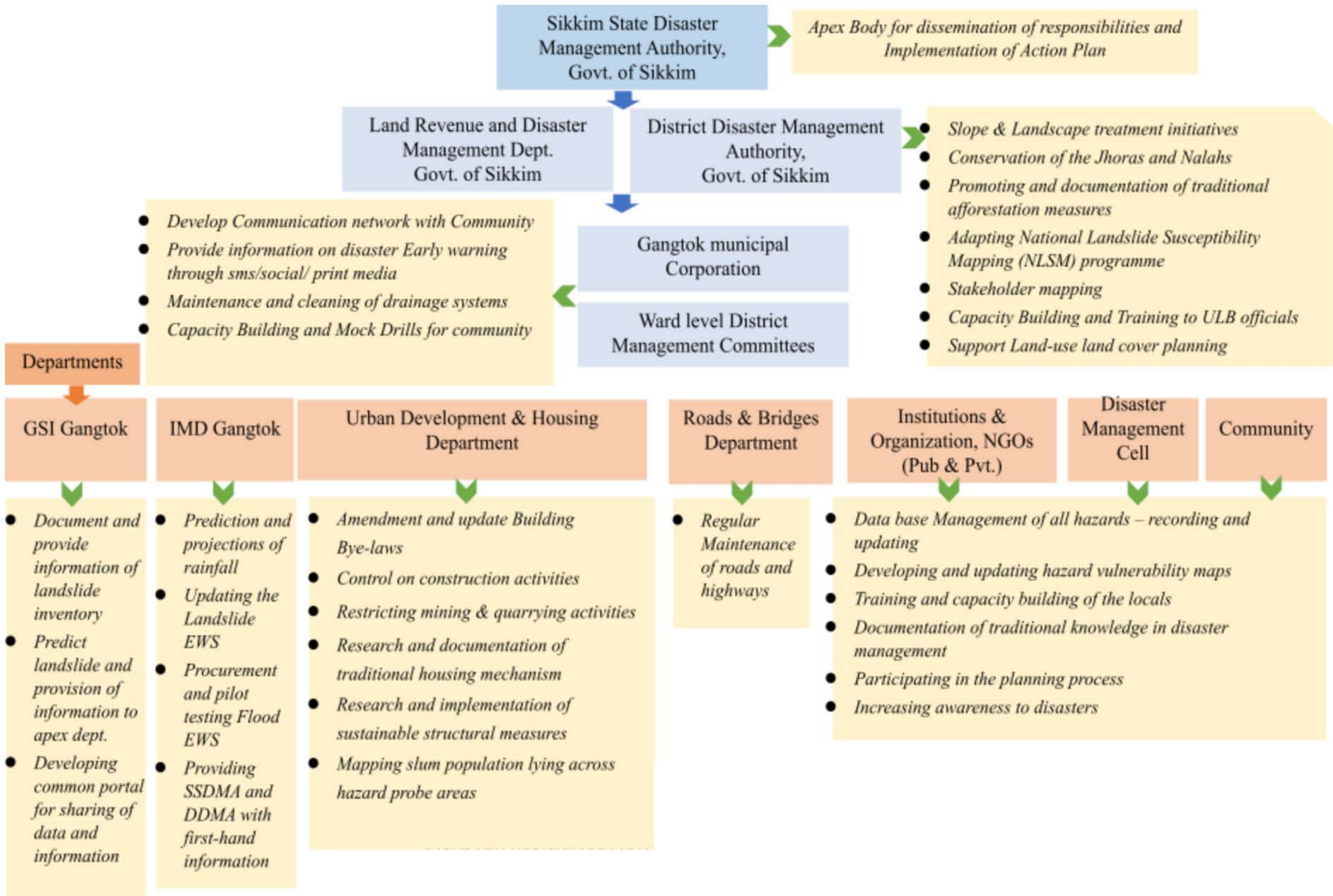
7.19.3 Flood

Time	Task/Activity	Department/Agency
Pre – Flood	1. Convening a meeting of the DDMA official, ESFs, EOC and other concerned institutions to take stock of department wise preparations.	DEOC/DDMA
	2. Take stock of functioning of the EOC and Control Rooms	DEOC/DDMA
	3. Closure of past breaches in river and canal embankments and guarding of weak points	Water Resources Dept
	4. Rain-recording and submission of rainfall reports	Water Resources Dept
	5. Communication of gauge-readings and preparation of maps and charts	Water Resources Dept
	6. Dissemination of weather reports and flood bulletins issued by the India Meteorological Centres & Central Water Commission	DEOC/DDMA
	7. Deployment of boats at strategic points, arrangement and use of power/motor boats	DEOC/DDMA
	8. Installation of temporary Police Wireless Stations and temporary telephones in flood-prone areas	DEOC/DDMA, Police/MPRO
	9. Storage of food in interior, vulnerable strategic and key areas and arrangements for their safety	DEOC/DDMA, Food Supplies dept.
	10. Arrangements of dry food stuff, essential medicines and other necessities of life	DEOC/DDMA, Food Supplies dept., Health dept.
	11. Alternative drinking water supply arrangements	PHE, SMB
	12. Arrangements for keeping the drainage system desilted and properly maintained	Water resource dept., MUDA
	13. Appropriate measures for Health, Veterinary services etc	Health & Animal dept.
	14. Identification /Selection of flood shelters	DDMA/DEOC
	15. Advance arrangements for army assistance if required	DDMA
	16. Training of department employees in flood relief work	DDMA
Post Flood	1. Report the occurrence of flood to DDMA, Heads of all line departments, ESFs, IRTs	DEOC
	2. Establish communication links by activating alternate communication equipments i.e. satellite phone, HF/ VHF set, HAM radio, VSAT etc.	DEOC/DDMA, MPRO, NIC
	3. Deploy mobile emergency communication unites to affected areas for establishing communication link	DEOC, BSNL
	4. Verify the authenticity of the flood event from agencies like IMD, Water Resource Dept, block level officers, police and fire department etc.	DEOC/DDMA
	5. Organize first meeting of duty officers	DEOC/DDMA
	6. Organize and dispatch the SAR teams to the affected areas.	DEOC/DDMA
	7. Ask for SDRF/NDRF/Army assistance as per requirement.	DEOC/DDMA
	8. Relief measures by non-official and voluntary organisations may be enlisted as far as possible.	DEOC/DDMA
	9. Organise relief camps and flood shelters	DEOC/DDMA
	10. Provision of safe drinking water to the affected communities	PHE dept., SMB
	11. Organise controlled kitchens to supply foods initially at least for 3 days.	Food supplies Dept., DDMA
	12. Provision of sanitation and hygiene facilities	PHE Dept, NGOs & Community Groups Health dept.
	13. Provision of health assistance and medical services	Health dept.
	14. Making necessary arrangements for air dropping of food packets in the marooned villages through helicopters.	DDMA, Air Force
	15. Establish alternate communication links to have effective communication with marooned areas.	BSNL, MPRO

	15. Establish alternate communication links to have effective communication with marooned areas.	BSNL, MPRO
	16. Organising cattle camps, if necessary, and provide veterinary care, fodder and cattle feed to the affected animals	AH&V Dept, Fisheries Dept.
	17. Grant of emergency relief to all the affected people.	DEOC/DDMA, Food Supplies Dept, Health dept
	18. Submissions of daily reports and disseminate correct information through mass media and district website to avoid rumors.	DEOC/DDMA, IPR
	19. Rehabilitation of homeless people	DEOC/DDMA
	20. Commencement of agricultural activities- desiltation, resowing	Agriculture, Horticulture, Fisheries Depts
	21. Repairs and reconstructions of infrastructural facilities such as roads, embankments, resettlement of flood prone areas.	Line depts
	22. Maintain constant communication with the onsite EOC	DEOC/DDMA
	23. Initiate relief distribution and recovery actions	DEOC/DDMA, Line depts

following departs were assigned responsibilities:

Resilience Action Plan Implementation Framework



12.3 Conclusion

NE region as a whole is expected to see an increase in average annual rainfall in 2030 with respect to 1970, with an average annual rainfall of 2,162 mm; Shillong is in close proximity to one of the wettest places on earth - Cherrapunji. The city has also experienced a rapid rise in temperature over the last 50 years. For the East Khasi Hills district (Shillong), the temperature increase is expected to be 1.6-1.7°C by 2050 (Meghalaya State Action Plan on Climate Change, 2015).

Along with the climate changes, the increased urban population has been gradual from 1901 to 1991; however, the growth rate has reduced remarkably due to the growth of the satellite towns in the Shillong Urban Agglomeration. The slum settlements in the city located in areas that are prone to landslides and flooding. Toe erosion in sparsely populated areas along the banks of river Umkhrah and Umshyrpi is increasing the vulnerability of slum settlements in these areas to landslides.

The urban vulnerability assessment indicated that due to rapid growth in urban population and unregulated construction work, the natural drainage system is blocked, leading to an increase in the frequency of urban flooding and landslides, thus increasing the city's vulnerability towards disasters. There is an immediate need to design and develop a drainage master plan for the city. Lack of sewerage management is affecting the water quality of the water bodies as well as groundwater. This also contributes to the incidences of waterlogging in the city. The integrated sewerage development plan needs to be developed and should be prioritized for investment.

The study of the existing Plans and the review of the actions initiated by Meghalaya Disaster Management Authority and East District Disaster Management Authority indicate that there is a need of strengthening the early warning system for floods and thunderstorms in the city. Development of Early Warning System (EWS) framework with involvement of all the key stakeholders. The Emergency Operation Centres (EOCs) should be equipped with the necessary equipment and latest technology. Well-trained staff in EOCs should be located in safe zones to avoid a halt in its functioning during floods.

In this respect, this Plan attempts to develop a comprehensive Disaster Resilience Action Plan for the city, with hazard susceptibility (landslides, flash floods and earthquakes) and existing critical infrastructure maps at the scale of 1:40000, at ward level. The plan emphasizes the short -medium-long term Structural and Non-structural resilience action strategies/measures to mitigate and adapt to the existing physical and socio-economic vulnerability. The plan also provides for detailed Implementation framework to strengthen the governance and administrative structure of the city while procuring and strengthening the early warning systems and preparedness methodology for improved risk management in Shillong.
IMD -functional need to be revised.

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About Project

Developing a Disaster Resilience Action plan through GIS and prioritising actions for Natural Disaster Risk Reduction in Urban Agglomerations of Shillong & Gangtok is supported by National Mission on Himalayan Studies (NMHS), under the Ministry of Environment, Forest and Climate Change Government of India (MoEFCC, GoI).

The project aims to develop Disaster Resilience Action Plans for Shillong and Gangtok cities; with objectives to develop ward level maps at the scale of 1:4000 and to map the hazard/disaster wise vulnerable zones of the Shillong and Gangtok urban agglomerations while identifying and mapping critical infrastructure at risk through ground surveys. This will assist in developing the Disaster Resilience Action Plan for the identified cities and prioritize actions for Disaster Risk Reduction in the Indian Himalayan Regions (IHR)

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