NEEDS OF RESILIENT STRUCTURE; A CASE STUDY OF FLOOD DISASTER IN PHUENTSHOLING, BHUTAN

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A thesis submitted to the Department of Architecture in partial fulfillment of the requirements for the degree of Master in Disaster Management.

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Declaration

It is hereby declared that

1. The thesis I submitted is written as original paper for the master degree at Brac University.
2. This paper is purely of my idea and all previously published materials had been given citations.
3. This paper also don't have materials already published in this university for any other degree.

I hereby state that the thesis title (**Needs of resilient structure a case study of flood disaster in phuentsholing, Bhutan**) is entirely my original work, except where otherwise indicated. I have acknowledged all sources of information and assistance, and I have complied with all academic and ethical standards as required by Brac University.

Ran Bdr Chhettri

20268010

Approval

The thesis "Needs of Resilient Structure: A Case Study of Flood Disaster in Phuentsholing, Bhutan" is submitted by Ran Bdr Chhettri (ID: 20268010) has been accepted as competent in partial fulfillment of the requirement for the degree of master in Disaster management on January 21,2024.

Examining Committee:

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Program Coordinator: (Member)	Muhammad Ferdaus Lecturer & Coordinator Postgraduate Programs in Disaster Management (PPDM) Brac University
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Departmental Head: (Chair)	Zainab Faruqui Ali, PhD Chairperson, Postgraduate Programs in Disaster Management Board Chairperson and Professor, Department of Architecture Brac University

Ethics statement

This research study, "Needs of Resilient Structure: A Case Study of River Flood Disaster in Amochu River in Phuentsholing," is committed to upholding the highest ethical standards throughout the entire research process. I affirm my commitment to conducting this study with integrity and honesty, presenting accurate and reliable information to contribute meaningfully to the understanding of resilient structures in the context of flood disasters. I recognize the importance of respecting the dignity, privacy, and rights of all individuals involved in the study, including community members, experts, and stakeholders. Informed consent will be obtained from all participants, and their anonymity will be preserved. Given the unique cultural context of Phuentsholing, Bhutan, I had approached the study with cultural sensitivity. I had engaged with the local community and stakeholders in a manner that respects their cultural norms and values. My primary goal is to contribute to the well-being of the community affected by the flood disaster. The research aims to identify the needs for resilient structures that can enhance community safety and preparedness.

I have committed to fostering collaboration with local authorities, community leaders, and other relevant stakeholders. Transparent communication had maintained throughout the research process to ensure the dissemination of information and the sharing of knowledge. Every effort that I made to minimize any potential harm to participants, the environment, or the community during the research. Risks had been assessed, and measures will be implemented to mitigate any adverse effects. This research had adhered to all relevant ethical guidelines, laws, and regulations governing research involving human participants. Institutional review board (IRB) approval will be obtained before the commencement of the study. The research had engaged in continuous reflection on ethical considerations throughout the study. Any ethical concerns or unforeseen issues that arise will be addressed promptly, and necessary adjustments to the research plan will be made.

Abstract

Climate change is contributing to changing of atmosphere which lead to lead to climate events including disaster such as river flood, landslide and glacial lakes outburst in Bhutan. The threat of river flood poses serious threat to the lives and livelihoods of the Bhutanese people. The continues downpour is leading to alarming volumes of water in downstream which also increase the forces and pressure because of high speed with mud, debris and stone as well. Increased in water level can't resist by the river training structure costing millions of dollars each year.

In response to the disaster, local authorities and the government of Bhutan initiated immediate rescue and relief operations. Evacuation efforts were carried out to ensure the safety of residents, and temporary shelters were established to provide them with essential supplies and support. Emergency services, including medical teams and disaster response units, were mobilized to provide medical care and assist in the recovery efforts.

The concern is that when the current bearing capacity of the structures not strong enough to resist the forces so water penetrate by breaking the wall and used to wash away the town during summer. My study area is in Toorsa river of Phuentsholing under Chhukha Dzongkhag basically the basin of the river. This phenomenon results in severe adverse impacts on downstream communities. A large number of people are vulnerable to river flood from Toorsa river. The risk of damage to their shops, washing away critical infrastructures, killing of cattle and even losing lives has increase in recent years. Hydropower, which accounts for a significant portion of the country's revenue involves huge investments in infrastructure and requires sustainable water resources.

The study is focused in assessing the Livelihood capital and Vulnerability of people living along the Toorsa river in phuentsholing town. Field data were collected from phuentsholing city cooperation, Thomdee and induvial interview as part of the case study. The information was collected through participatory tools and further followed by DIFDs livelihood analysis guidelines and valuable studies from Japan and Bangladesh on flood resistive structure to manage flood risks. To assess the information, literature was reviewed from different journals, books, government policies, meteorological and hydrological data and other unpublished thesis work and articles.

The immediate installation of warning system and resilient structure for Amochhu settlement was commanded by His Majesty to High Level COVID-19 Task Force to warn community of flood, who will be settled in the shelters under construction on the Amochhu river banks. The High Level COVID-19 Task Force directed NCHM to install the Flood Early Warning System and resilient structure as soon as possible but still not come up with good idea. NCHM management started working instantly with preparation and planning to install the system with the available spares in stock and market.

The flood disaster in Phuentsholing was triggered by heavy and prolonged rainfall, which caused the rivers in the area to swell rapidly beyond their capacity. The excessive water flow overwhelmed the riverbanks and infrastructure, leading to widespread flooding in the city. The floodwaters inundated residential areas, commercial establishments, and critical infrastructure such as roads, bridges, and public utilities.

The consequences of the river flood disaster were devastating. Numerous homes and buildings were damaged or destroyed, resulting in the displacement of a significant number of residents. The floodwaters also disrupted transportation networks, making it challenging for emergency services to reach affected areas and provide assistance to those in need. Additionally, the flooding contaminated water sources and increased the risk of waterborne diseases, posing further health hazards to the affected population.

The river flood disaster in Phuentsholing highlighted the vulnerability of the region to natural hazards and the importance of disaster preparedness and resilience. Efforts to rebuild and rehabilitate the affected areas, improve infrastructure resilience, and implement early warning systems for flood detection and response were initiated to mitigate the risk of future disasters.

Overall, the river flood disaster in Phuentsholing had significant socio-economic and environmental impacts, underscoring the need for comprehensive measures to mitigate and manage flood risks in the region.

Keywords: River flood disaster, flood risks, Emergency services, Resilient structure.

Acknowledgement

I would like to thank my supervisor Mr. Khurshid Alam who is working as a Deputy Resident Representative of UNDP from Bangladesh to Bhutan for your good time and valuable input. Without your help and support it may not be possible to complete this thesis on time as well as may not get all the information as required in standard thesis. As far your idea I change my topic slightly which make me more comfortable to come up with strong evidences which make my thesis stronger.

Also thankful to Mr. Mahammad Ferdaus, program coordinator (PPDM) for your generous support for entire duration of the thesis writing. Your help and support really assist me to getting more knowledge on data collection and data interpretation. Without his assistance it may not be possible to complete this thesis on time. I also thank you for introducing me to get in PPDM program in BRAC University.

To National housing development cooperation (NHDCL) for their great help to get data from long time back without any charges. Without their help my thesis may left incomplete. So, three cheers for them. I also would like to thank Construction Development Cooperation (CDCL) for more data assistance about the impact of river flood in phuentsholing as they are working there to improve the situation. Let's not forget department of metrology and hydrology (DMH) for providing me river flow data from 2007-2021.

Let's not forget my mate from 2020-2022, as you all made my stay really remembering one and we all share good memories during our entire course. I found some of you had good experiences and I learned from you a lot. I am thankful to youth development fund (YDF) for giving me chance to do my master in disaster management in Bangladesh, without your help I am not able to do my master with my own afford. To entire family of BRAC University specially the international department, I don't have enough words to say thank you since you bring me light and aspiration as providing me full scholarship to do my master's degree in your university. I will never forget you for your enormous help and support by which I successfully completed my degree.

Lastly but not the least, I thanks to my beloved parents for your greatest help and support to do my master. Your non-stop encouragement really helps to grow my feelings to do this research and I am with some knowledge of wisdom which help me to help in the field of disaster management.

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LIST OF Abbreviation

ADPC Asian Disaster Preparedness Center
BHU Basic Health Unit
CBDR Community Based Disaster management
DDM Department of Disaster management
EWS Early Warning System
FGD Focus Group Discussion
GEF Global Environment Facility
IPCC Inter-Governmental Panel on Climate Change
NAPA National Adaption Program of Action
NEC National Environment Commission
NGO Non-Government Organization
SLF Sustainability Livelihood Framework
UNDP United Nations Development Program
UNISDR United Nations International Strategy for Disaster Reduction

CHAPTER ONE
Introduction

1.1 Background of Research Study

Bhutan is located between two big countries China in the north and India in the south with area of 38,394 sq.km, and total forest area of 32,166 sq.km as shown in fig.1.1 and fig.1.2. Approximately 72% of the country is forest. As mentioned in our constitution of Bhutan demands that 60% land shall be maintained as forest at all times. The northern part of the country is fully covered by great Himalayas of 340km. With population of 800,000 people (783,603 in 2021 based on PHCB 2017 projections). The country has three distinct climate zones: Humid and sub-tropical in the southern plains and foothills, Temperate in the inner valleys and cold in the alpine north with year-round snow cover on the peaks.

Bhutan is carbon negative country. But global warming has led to climate change especially increased frequency causing climate induced disasters. River in Bhutan covers about 12 percent of the total surface area. According to International Centre for Integrated Mountain Development (ICIMOD) and United National Development Program (UNDP) of Bhutan marked the presence of major four rivers namely Drangme chhu, Mo chhu and Toorsa chhu covering an area of 7200km, and all rivers have potential threat to people and environment. Among four rivers I want to talk on Toorsa chhu which is flowing from China passing southern Bhutan so call Phuentsholing to get into Brahmaputra.

According to NEC outlook 2008(Barnett et al,2005), the rivers in Bhutan are too narrow so that it can cut away anything which meet on its way during monsoon season. The inherent instability of moraine or ice dam can be triggered easily by other hazard, like Avalanches, Landslide, Rock fall. The immediate discharge of huge volume of water and debris pose threat to lives and livelihood asset in the downstream town and urban population. Some rivers that are in disequilibrium with present climate change have already disappeared. This phenomenon of flooding is called “River flood”. Rivers are among the most serious natural hazards potential in the country. River disasters have taken place in Bhutan in the past every year which already made huge lost in economic. Downpour which also lead to landslide and the main sources of fresh water in the county. Generation of electricity, which is 60% of country’s economic generator is also based on the fresh water flourish. The truth is that Bhutan’s economy is highly dependent on hydropower generation it is term as “WHITE GOLD” (water). It is Bhutan greatest revenue which is needed to preserve. Hydro-electricity is adopted sometimes in the

year 1966 in which only 256 kw diesel generating plant was installed to supply power to Phuentsholing.

Increased rain in mid-summer would cause great flow for many decades in Bhutan but some areas of the most populated region on Earth are likely to run out of water (Barnett et al, 2005). But in other hand River flood can be very devastating to property of many people and lives every year in Phuentsholing town since it is a economic corridor. As we know our huge portion of population are settled in Phuentsholing since it is trade hub to the outside world through land. livelihoods of Bhutanese people are vulnerable, and it also causes of huge damages to important infrastructure such as private building, shops and vehicles as well. All most all the settlements in Bhutan are along the river valley but more destruction in Phuentsholing since from long time back. Although government took seriously to control flood but still it is not under control which give me attention since that is the common points which is affected by river flood disaster and more importantly responds to deal with event (Dynes, 2006).

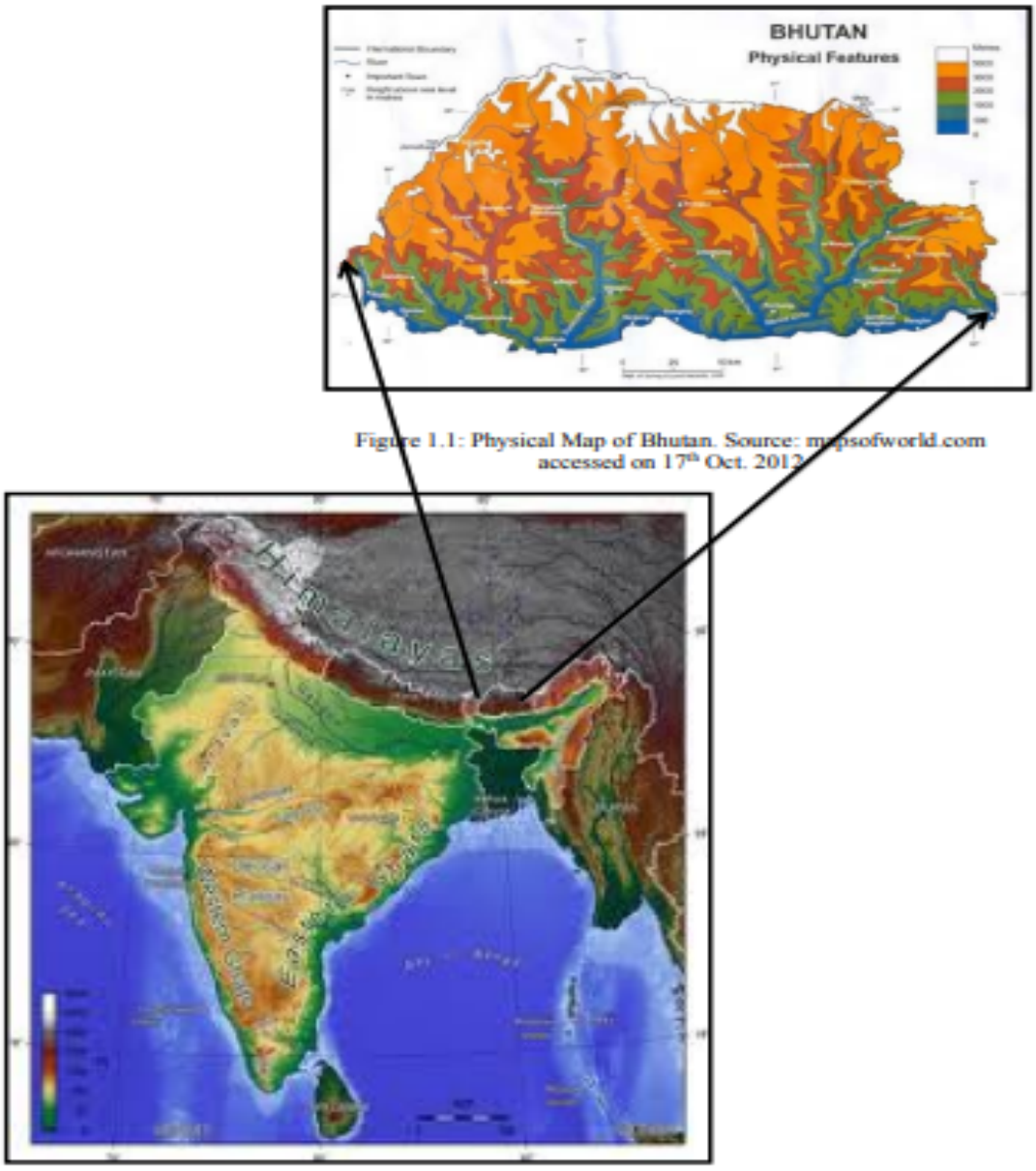


Figure 1.1: Physical Map of Bhutan. Source: mapsofworld.com accessed on 17th Oct. 2012

Figure1 showing Bhutan in Asian map

1.2 Problem and Justification of Research

In this article, I want to support and suggest Community Based River flood Disaster Management in order address river flooding in Bhutan which can minimize and strengthen community approaches and it may help us to strengthen the capacity and resilient of town. The failure of a natural as well as man-made structure became hazardous for the people who are settled nearby Amochu river. River flood impact at downstream where town livelihood is being destroyed which can reduce its vulnerability and risk by flood resilient structure.

1.3 Objectives

Objective: Assessing detailed flood assessment of Amochhu River in Phuentsholing under Chhukha Dzongkhag.

1.3.1 The specific aims and objective are to:

- Assess the current flood vulnerabilities in Phuentsholing to identify key areas requiring resilient structures.
- Investigate the existing infrastructure in Phuentsholing and determine their limitations in addressing flood risks.
- Develop a comprehensive understanding of the specific needs and preferences of the community regarding flood resilient structures.

1.4 Research Questions

- what are the key environmental challenges faced by structures in the Amochu river in Phuentsholing?
- Are these specific geological or hydrological factors in the Amochu river that need to be considered for designing resilient structures?
- What technologies and materials are most suitable for constructing resilient structures in the challenging environment of the Amochu river?
- How can sustainable practices be integrated into the construction and maintenance of structures in the Amochu river to enhance long-term resilience?

1.5 Thesis Outline

The article is divided into five main chapters. In first chapter I included introduction gives a brief overview of global climate change and the change in seasonal atmosphere and impact on livelihood. It also included on presence of rivers in Bhutan and the past river flood events and Impact on public and private structure. The Implication of river disaster which cause the loss of livelihoods downstream town also included research objective and questions. In chapter two I included literature review with background information on hazards and risk of river flood. Methodology and data collection included in third chapter. In forth chapter, I presented result by discussion. Chapter five have Significant of the study.

1.5.1 Study area

Bhutan is having twenty districts in which my study area is in Chhukha dzongkhag in phuentsholing geog.

Fig 2 Map showing study area and Amochu River.

CHAPTER TWO

Literature Review

2.1 Terminology used in the research

2.1.1 Climate Change

Climate change refers to as long term statistically important change in the entire country or part of some country by means of greenhouse gas emission persisting for an extended period. The change may be because of natural processes or change from manmade utensil or to persistent anthropogenic variation in the atmosphere (IPCC, 2001). Climate change is a human induced process related to Greenhouse gas emission which is now becoming disaster to the entire world. Due to this change, there is vast change in rain fall pattern which give us fear in near future.

2.1.2 Global Warming

The Global Warming refers to the rise in the global temperatures due mainly to the increasing concentrations of greenhouse gases in the atmosphere of our mother earth and water bodies in the past, present and in the future. The backbone of global warming are man-made causes, such as greenhouse gas emission, solar variation and natural causes.

2.1.3 Climate Variability

Climate variability can be the change in the mean country and other data (such as standard deviations, the occurrence of extremes, etc.) of the climate change on secular and geographical scales over that of particular weather events. Variability can be because of natural process within the climate change system (internal variability) (IPPC, 2004).

2.1.4 Hazard

Hazard is an outcome of natural and manmade events which potentially damaging our properties, loss of life or injury, economic, social disruption and environmental damage. Hazards can be natural such as geological, hydro-meteorological and biological and man-made hazard can environmentally damage and technological hazards. Hazards may be monomial, sequential and combination of both. Each hazard is characterized by its location, intensity, frequency and probability" (UN/ISDR, 2009).

2.1.5 Vulnerability

The condition determined by physical, social economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. (UN/ISDR, 2004). It is a quality of being exposed to the possibility of being harmed physically or emotionally. For example, telling others when they have done something to upset you.

2.1.6 Vulnerability Assessment

Vulnerability assessment can estimate the physical, environmental, economic and social factors or processes which maximize the susceptibility of the places to the impact of hazards. Particularly useful tools are: social vulnerability mapping, physical vulnerability mapping, seasonal calendar, transect walk, direct observation and interview (IPPC, 2004).

2.1.7 Risk

It is a situation to exposure to any danger or expected loss of lives, property, livelihoods, and environment damaged due to combination between natural or human induced hazards and vulnerable conditions. Risk is calculation can be shown by equation: Risk = Hazards X Vulnerability (UNDP, 2004).

2.2.8 Disaster

It is a serious problem occurring in a short or long period of time that can causes huge loss on lives, materials, environment and economic which exceeded the ability of hamper community by using own resources (ADPC,2009).

2.2 River flood in Bhutan

2.2.1 River

In general Bhutan had four big River's system from where we can generate more than ten thousand GW electricity and sell to India in present. In monsoon due to heavy rainfall this the quantity of water increases with mixture of debris which also increase intensity which are non-stoppable by natural as well as man-made structure in any of the rivers. Due to this reason upon each other and gradient of slop at certain state they begin to cut the bank. In Bhutan rivers is the largest water body of freshwater. And also, rapid melting of Glacier Lake threatened the glacier lake outburst flood too (ICIMOD, UNFE 2001).

2.4 The Resilience Concept in Japan

The United Nations Office for Disaster resilience structure explain resilience as the capacity of a community who are exposed to hazards to absorb, accommodate, resist, adapt to change and recover from the exposure of a hazard in a regular and good way including preservation and restoration of all such structures and functions through risk management(kato,2012). In order to strengthen flood resilience structure, detail evaluation of institutions, reduction and risk identification, preparedness for the particular disaster, social and financial protection reconstruction should be given first parity. Arguing in engineering resilience is recommended for fast recovery and the risk in cities/town can make up by recognizing recoverable impacts(kota,2012).

The government of Japan is taking initiatives for nation wise resilience structure to create safe, awareness and secure national regions/lands and economic community that have strengthen and promote flexibility during the event of any disasters. Their basic aims are (a) to prevent loss of live (b) to avoid fatal damage of properties (c) to mitigate damage to property and loss of live of the people and public facilities and (d) to enhance fast recovery and reconstruction(kota,2012). The government of Japan planned to invest some 64 billion USD or 7 trillion JPY in disaster resilience infrastructure development to reduce disaster risk until 2020 from 2018.

The government of Japan used resilience as the tool of minimizing damage/harm from any water related disaster by keeping in the mind fast recovery and promoting sustainable and equitable cities. However, some researchers/experts used resilience with alternate meanings since there is no common disaster resilience theory. Many Studies had found out that how different sectors used to contribute to promoting community resilience in Japan specially in the field of flood disaster. Some of the authors also used to argue on community networks created in healthcare by medical and local government sectors to promoting community's resilience in the country. After the great east Japan earthquake in 2011 education ministry of Japan, school and Community Building. In any disaster in Japan schools become multi-functional room for handling disaster management and its victims by forming local communities in educational activities.

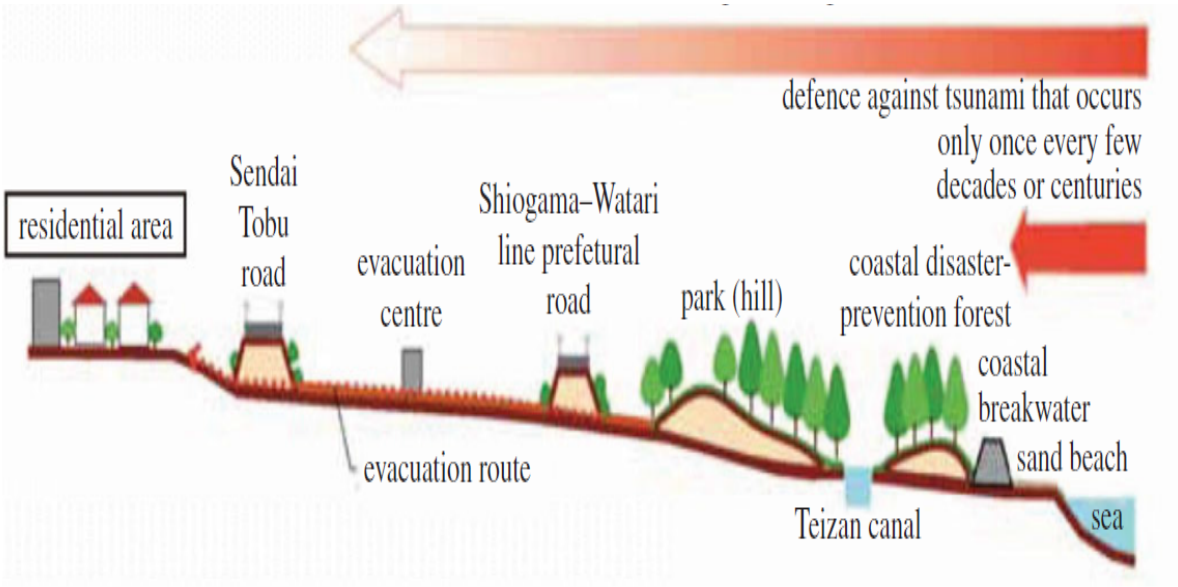
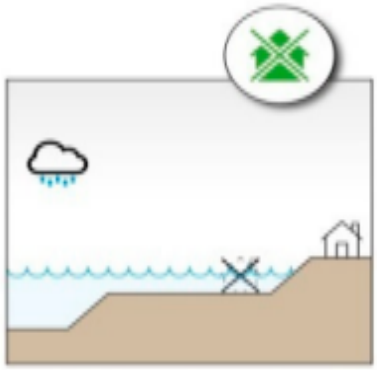


Fig3 Japanese model for flood

2.4 **Key Governance Strategies for Enhancing Flood Resilience in Bangladesh**

Bangladesh is one of the most disaster-prone countries in the world and this section highlighted each of the six governance strategies which are commonly mentioned on their country comparison. Researchers are increasingly argued that the capacity to resist floods by flood resilience structure which can absorb and recover from floods so as adapt and transform requires diversified portfolio of flood risk management approaches (Bouwman,2016).

Mode	Characteristics
1. Flood risk prevention	
	Prevention measures aim to **decrease the exposure of people/property** etc. via methods that prohibit or discourage development in areas that are at risk of flooding (e.g., spatial planning, re-allotment policy, expropriation policy etc.). The main focus of this approach is on "keeping people away from water" by only building outside flood-prone areas. This is a pro-active strategy that focuses both on probability reduction (if people do not live in flood-prone areas, then it is unlikely that they will get flooded) and the consequences of flooding (an area may still be flooded, however in the absence of large-scale urban developments, the consequences are relatively small).

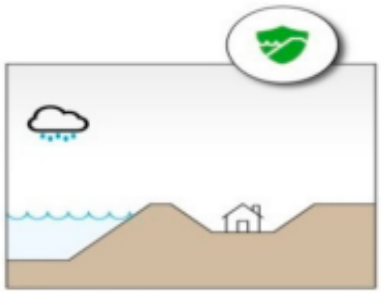
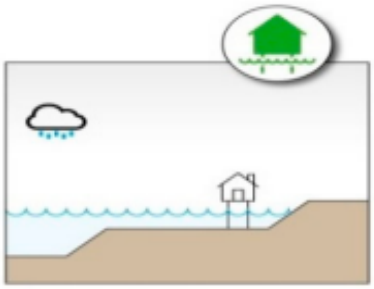
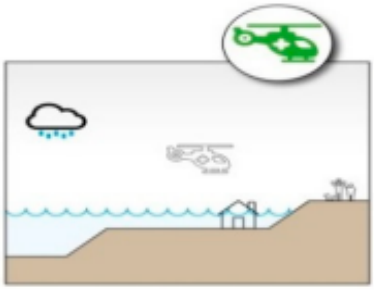
2. Flood defense	
	Flood defense measures aim to **decrease the probability of flooding** areas through infrastructural works, such as dikes, dams, embankments and weirs, mostly referred to as "flood defense" or "structural measures" through options that increase the capacity of **existing** channels for water conveyance (natural or man-made) to increase the space for water (laterally or vertically) or the creation of **new** spaces for water retention **outside of the area to be defended**. In brief, the focus is on "keeping water away from people".
3. Flood risk mitigation	
	Flood risk mitigation focuses on **decreasing the consequences of floods through measures inside the vulnerable area**. Consequences can be moderated by a smart design of the flood-prone area. Measures include smart spatial ordering inside urban areas, water retention within the protected area, or (regulations for) flood-proof building. Flood risk mitigation thus includes all measures to flood-proof the built environment as well as measures to retain or store water.
4. Flood preparation	
	**Consequences of floods** can also be alleviated by **preparing for a flood event**. Measures include developing flood forecasting and warning systems, as well as preparing disaster management and evacuation plans.
5. Flood recovery	
	This approach **facilitates an effective recovery after a flood event**. Measures include reconstruction or rebuilding plans (that may also provide a window of opportunity for making the new buildings more flood-proof or relocate these to safer areas) as well as compensation or insurance systems.

Table2 Risk management approaches in Bangladesh

Figure4 Flow information of disaster in Bangladesh

Every mode as shown above have different ways to reduce risk of flood in terms of flood consequences and flood exposure but it is found that combination of this modes can drastically reduce flood risk in Bangladesh. A global portfolio of greatly working flood risk management techniques/approaches is must in order to address the three-resilience capacity. The flood training techniques can improve capacity to resist, though their four strategies can improve the capacity to recover and absorb and the capacity to adapt and transform (Krysanova; Kanae,2017).

Each Countries had their own advantage and disadvantage identifying and implementing flood risk management approaches. Moreover, come up with complementary approaches to promote flood resilience is challenging everywhere. European country like Netherlands had gain several experiences to fighting against the water. The delta program is the Netherlands approach to flood risk management, an elaborate system of Dams, sluice gates, storm surge barriers, and other protective measures. The program also brings together experts on water management, civil society, and authorities from all level of government (5 facts,2016). This country had good record regarding flood defense. Moreover, the flood-defense approach is highly institutionalized (Krysanova; Kanae,2017). However, in new era new ideas have started to have greater impact on flood management. From the early 1990s the over ruling kept the H2O out paradigm has been implemented with alternatives for the river flood strategies that can be seen as a broadening within the flood defense techniques.

In second phase the river flood management has been further improvement of flood mitigation and recovery strategies and come up with flood risk prevention and control techniques have been gain more prominence in law discourses so there are more experiments in the new approaches. In the smooth situation the over ruling capacity was to find out river flood defense first although the truth that Polish H2O management agencies face difficulty from a massive lack of resources (Krysanova; Kanae,2017). Unlike other floods 1997 and 2010 floods have given an impetus to the improvement of improved flood forecasting and early warning systems. But the further improvement of the other techniques is proceeding very gradually every year. Both in The Poland and Netherlands there is a relative dominance of flood defense which contributes to path dependency.

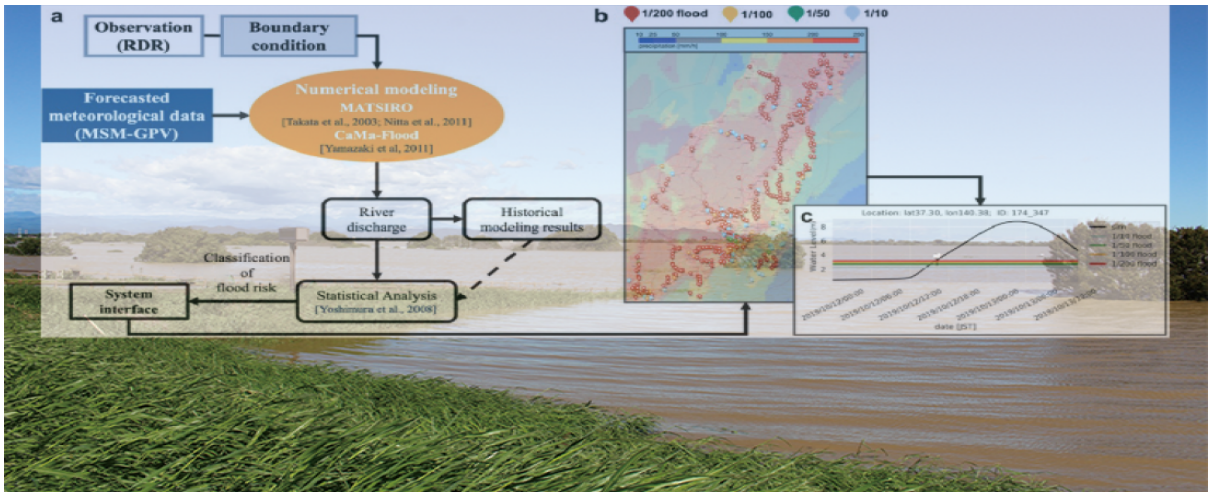


Figure5 Data forecasting model of Bangladesh

2.5 Need for being resilient in India

Almost 24 percent of deaths cases due to disasters occur in India as it is highest number in Asian continent due to its population and vulnerability by flood. India had a strong history of victims by floods starting from 1987 floods in Behar, 2005 flood in Maharashtra, 2012 flood in Assam, 2013 flood in Uttarakhand, 2014 flash flood in Jammu and Kashmir and recently 2015 flood in Chennai. 324km2 of total geographical area 40km2 are flood prone (Gupta et al,2016). 53 Indian big cities which have a population of more than a one million and of these 25 are in the coastal states according to census report 2011. Those are the largest cities expose to flood hazard such as Mumbai and Kolkata feature in the list. Although they spent thousands of crores in flood management but their infrastructure still shows weak performance during the flood hours.

Figure6 flood in Indian city, Chennai

2.6 Process of resilience to negligence

As we all know that most cities in the world ignore long term climate impact thus not resilient and its respond to any disaster is very weak. But those urban cities which designed to climate impact has ability to respond to its to disaster more sensitively and it is the example of successful existence over the years. But contemporary planning process it digs enough to increase non-inclusive urban development across these cities. As a result, pre-dominantly modernization steps are struggling with cities in most vulnerable condition. Because of this many people become prime victims of climate related calamities in these days.

Resilient methodology in India

A diverse group of people varying from local government officials, scientific experts, research centres, civil society and private sectors came together to discuss on flood disaster by the process of knowledge sharing to find out the key priorities, gaps and needs in the cities (Gupta et al, 2016). Joint problem-solving facilities have been designed to facilitate mutual learning in the project city to identify the linkages on urban growth, development, climate change, vulnerability of people by incorporating open communication between various stakeholder groups (ACCCRN, 2013).

2.7 On-Going Action for river flood in Bhutan

Government of Bhutan is much more aware of the current situation of the river flood specially in the southern part of Bhutan. During monsoon season all southern border are flooded with river flood due to excessive downpour thereby posing a serious threat to the lives and livelihood of the Bhutanese people. Our ordinary structure is facing difficulties to resist water pressure. Every year government spend some limited amount of money as for our capacity but it does not come up expectation and resistive in which our work done use to come to zero in summer. We are still not come up with good quality flood water resilient structure due to that we are losing many lives as well as resources every year. The outcome of the first project which shows improvement on national, regional and local capacities to prevent Climate Change. River flood disasters is addressing the needs to incorporate climate change into ongoing disaster risk management decision making and practices (Gyeltshen,2014).

Some of the artificial measures taken in lowering the water levels as well as water pressure that can change structures may trigger catastrophic discharge events. Due to greater water pressure, it will cut away any structure during summer and it is likely to be useless. The river training in Amochhu river is going along with town planning work since a year but no good result yet. The outcome of third project comments to reduce human and material losses in vulnerable communities such as Phuentsholing, Gelephu and tsirang. The outcome of forth project is also comments on digital learning, evaluation and adaptive management in which the learning and knowledge exchange showing the replication of effective disaster risk reduction actions and adaptation to climate change both within Bhutan and with other countries facing climate change (Gyeltshen,2014).

Figure7 River flood overview

2.8 River flood in Bhutan

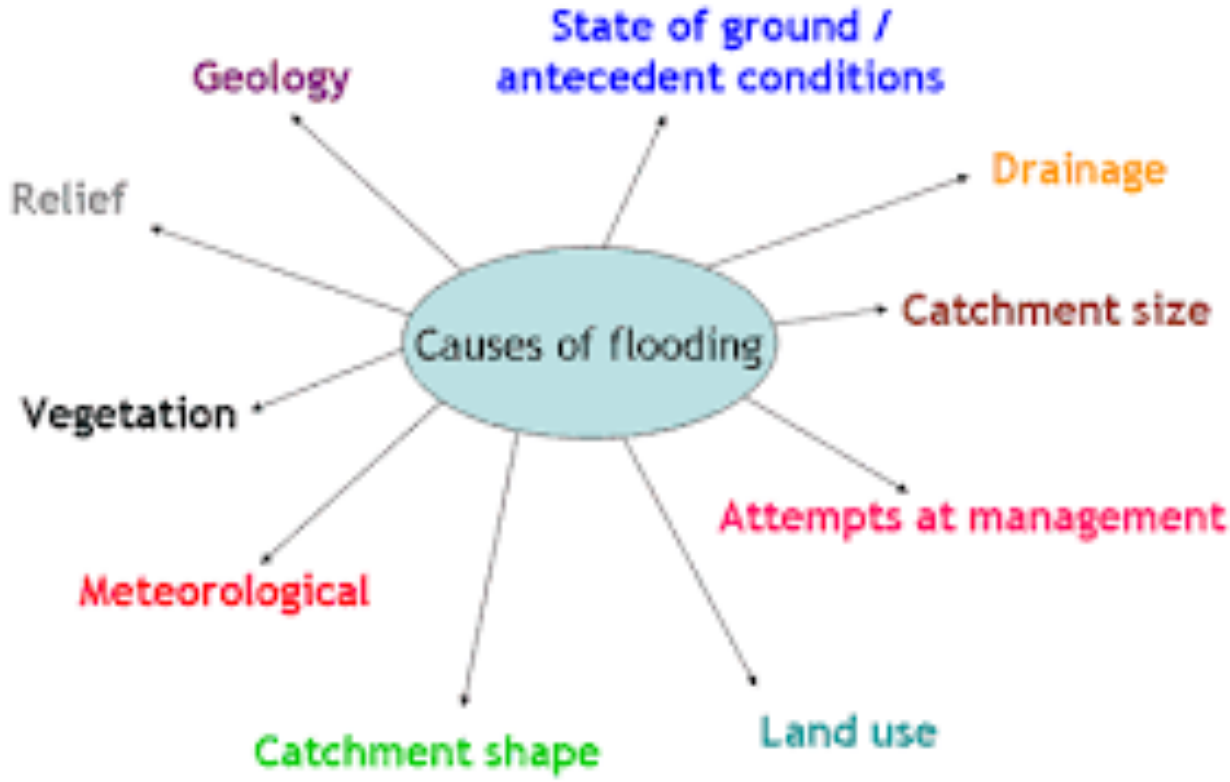
Though our country had more than 60% forest coverage, but the important factor related to river and flash flood is the loss of vegetation due to development activities. This exposes our fragile ecosystem to more hazard. The southern foothill of Drukyel also known as thunder dragon has an intensively dissected terrain with deeply eroded and it is steep and closely spaced gullies, river valleys and gorges which often experience floods caused by tamandus rainfall during raining season from June to September. Which is susceptible to damage the industrial infrastructures such as hydropower projects and low-lying bridges and all the infrastructures along the town.

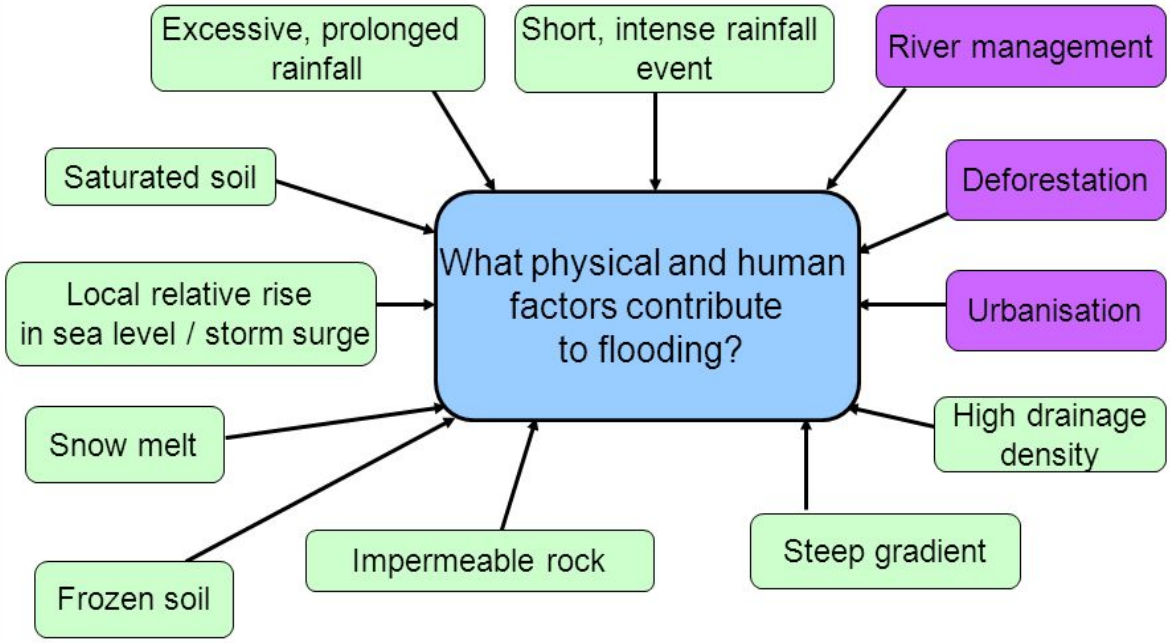
Figure8 flooding in phuentsholing

Figure9 flood destruction in phuentsholing

2.9 River flood and its causes

River flood has different mechanisms such as lake outburst, dam burst and heavy rainfall, which mainly depend upon the stability, and material of dam are made up off, the position and direction of lake location, content of water volume, topographical and physical condition and it also depend upon surrounding condition. Main trigger events which lead to river flood are…





2.10 Flood management approach in Bhutan

2.10.1 Manual Early Warning System

Because of limited resources and least develop in terms of technology manual local resources makes very effective in times of disaster. In Chhukha Dzongkha there are ten mobile phones were provided to early warning focal person in ten different locations along the disaster-prone area with a flex load of Nu.50 on a monthly basis. But in 2010 flex load is raise to Nu.150 per month as comment by the Dzongkha focal person on disaster management. As mentioned by the focal person the use of mobile phones proved to be very reliable to communicate in any case of early warning from the particular disaster point to the communities. Focal person is asked to gather any disaster related information by the Dzongkhag in monthly bases. The manual early warning system is good and should function even with the installation of the automatic early warning system in the country. In case of river flood disaster almost half of the total respondents in phuentsholing felt the event which occur during periods of heavy rainfall.

To develop a manual early warning system for river floods in Phuentsholing, we would need to consider several factors. Here is a step-by-step guide to help you set up such a system.

1 Understand the local geography and river systems: Gain a thorough understanding of the rivers in the Phuentsholing area, their behavior during heavy rainfall, and their flood-prone areas. Identify the key rivers that pose the greatest risk.

2 Establish a network of monitoring stations: Set up a network of monitoring stations along the rivers to measure water levels and rainfall. These stations should be strategically located in areas prone to flooding and should cover the entire river basin.

3 Define trigger levels: Determine the water level thresholds at which floods are likely to occur. This can be based on historical data, expert knowledge, and consultation with local authorities. Different trigger levels can be established to indicate different degrees of flood risk.

4 Install monitoring equipment: Install water level gauges and rain gauges at each monitoring station. These devices will provide continuous data on water levels and rainfall. The equipment should be regularly calibrated and maintained to ensure accurate readings.

5 Establish a communication system: Set up a reliable communication system to transmit data from the monitoring stations to a central control room or a designated authority responsible for issuing flood warnings. This can be done through wireless communication or a combination of internet-based and traditional methods.

6 Develop a flood warning system: Design a system that takes into account the trigger levels and the rate of rise in water levels. Based on the monitored data, the system should be able to issue timely flood warnings at different levels of severity.

7 Define response protocols: Work closely with local authorities, emergency services, and community leaders to develop response protocols for different flood scenarios. Clearly outline the actions to be taken at each level of flood warning, including evacuation plans, deployment of resources, and coordination among relevant stakeholders.

8 Raise public awareness: Conduct public awareness campaigns to educate the local population about the flood warning system, the meaning of different flood alerts, and the appropriate response actions. Ensure that the information is accessible to everyone, including those with limited literacy or language barriers.

9 Test and refine the system: Regularly test the early warning system to ensure its effectiveness. Conduct drills and simulations to assess the response time, coordination, and communication processes. Use feedback from these exercises to refine the system and address any identified shortcomings.

10 Review and update: Periodically review the system and update it based on changes in the local environment, new data, technological advancements, or lessons learned from previous flood events. Continuously seek feedback from stakeholders and make necessary improvements to enhance the system's reliability and efficiency.

Remember, a manual early warning system is a valuable tool, but it should be complemented by other measures such as infrastructure development, land-use planning, and community preparedness to effectively mitigate the risks associated with river floods.

2.10.2 Automatic Early Warning System

United nation development program (UNDP) with Royal Government of Bhutan had launch project in institution of early warning system to the river flood affected area after 2016 flooding but as far my survey in 2022 many cooperate; private and other local firm told me that the installation of automatic early warning system was just a story. This initiative has installed 25siren tower and 10 hydro-met monitoring stations in all around the Dzongkhag remained incomplete (Chukha,2016). Bhutan metrology and hydrology also play significant role to provide weather focusing daily data which also alert the system automatically (Bhutan hydrology,2017). Many livelihoods and property have been safe after the installation of early

warning system in Amochu. I encourage Royal Government Bhutan to installed early warning system as far as possible so that the population in new settlement area feel safe during monsoon. An automatic early warning system is crucial in mitigating the impacts of floods and ensuring the safety of communities. While there is no specific information on the current status of the Phuentsholing River flood early warning system as of now, I can provide you with a general overview of how such a system typically operates.

1 Monitoring Infrastructure: The system relies on a network of sensors and monitoring devices installed at key locations along the river. These devices can include water level gauges, rainfall sensors, weather stations, and river flow meters. The sensors continuously collect data and transmit it to a central monitoring station.

2 Data Collection and Analysis: The data from the monitoring devices is collected and analyzed in real-time. The analysis includes tracking changes in water levels, rainfall intensity, and other relevant parameters. Advanced algorithms can be used to assess the risk of flooding based on historical data and current conditions.

3 Trigger Levels and Thresholds: The early warning system establishes trigger levels and thresholds for various parameters. For example, a specific water level or rainfall intensity may indicate an imminent flood threat. When these trigger levels are crossed or exceeded, the system is activated to issue warnings.

4 Warning Communication: The system employs various communication channels to disseminate warnings to relevant authorities and communities at risk. These channels can include SMS alerts, mobile apps, sirens, radio broadcasts, and community loudspeakers. It's important to ensure that the warning messages are clear, concise, and easily understandable to facilitate prompt action.

5 Emergency Response and Evacuation: The early warning system should be integrated with emergency response plans and evacuation procedures. Local authorities, emergency services, and community leaders should be well-prepared to take immediate action upon receiving the warnings. Evacuation routes, shelters, and contingency plans should be in place to facilitate a swift and organized response.

6 Public Awareness and Education: Alongside the technical aspects, community education and awareness programs play a crucial role. The system should be accompanied by public campaigns that educate residents about the meaning of different warnings, appropriate response actions, and the importance of preparedness.

It is important to note that the implementation and effectiveness of an early warning system depend on various factors, including funding, infrastructure availability, data accuracy, and

community participation. It's recommended to consult with local authorities, experts, and relevant stakeholders in Phuentsholing for detailed and up-to-date information on the specific early warning system in place for the Phuentsholing River flood.

2.11 Hazard Zonation Concept

To identify hazard-prone areas in river side where there is a maximum number of people settled, sustainable livelihood and other properties such as vehicles, bridges and buildings where people invest maximum were demolished and destroyed by river flood. So, it is very important for Hazard zonation demarcation in hazard prone places in which there is lots of infrastructure and community assets. This zonation concept will help in providing useful information in disaster risk management teams and other institution in marking hazard prone zone and vulnerable area in phuentsholing. The project for risk area zonation is started from 1998 in collaboration with Australian government for hazard zone demarcation and came up with map in which all hazard zonation concept is included. Hazard zonation areas in phuentsholing were categorized in three major types based upon the degree of risk exposed to river flood and represented with three color coding.

2.12 Identification of Safe Evacuation Area

To get a Safe and secure evacuation area is a first criteria in times of any disaster in order to reduce to loss. It is very easy to proceed with secure location once the hazards zone map is drawn. The department of department of Geology and Mines and department of disaster management had not yet identified evacuation area for Phuentsholing town. Some of criteria had been identified which are not still mandate as mention below.

•They are still not come up with particular evacuation centre if river flood hit the city.

• The area should be near to possible distance from the city which is not yet plan.

• The evacuation centre should be open and not used land which is not plan.

• The identified area be at a safe location during river flood.

Community Based Approaches to Disaster Management

People volunteer is another as combine element in disaster management and disaster risk management which is needed to change the global way of critically rise in disaster event occurrence which profound to loss from light and heavy scale disasters and also come up with safety and make sure on sustainable development for whole citizens. Bhutan disaster management already took step to reduce risk on phuentsholing river flood in which community who had problem or at risk are actively joined in the identification, evaluation and monitoring process in order to reduce their vulnerabilities promote copping capacities.

It is highly indicated that the people are wisely engage in decision-making as well as implementing of disaster risk reduction approaches in disaster affected areas. Either the small or large disaster always this people are facing adverse effects. People in this place adopted survival and coping strategies to respond to the events before long time arrival of government and non-governmental organization.

2.13 Disaster Management?

As quoted by someone that all hazards cannot be disaster, but all disaster will be a hazard so if any event which don't have potential to take lives and properties is always hazard but if the event won the coping capacity of community and loss of lives and damages of properties took place that it is a disaster. People's livelihood is affected by disaster but single person afford toward community building are significant to reduce the potential impact of particular disasters. Human security is so called disaster management. Lots of natural as well as manmade disaster for example floods and drought and Glacial Lake outburst is directly indicated environmental degradation and climate change. Specially this disaster hurt the poor people since they are having limited properties with tamandus hard work in their life because they are potentially weak to disaster as they are financially poor. In order to create disaster resilient communities to improve disaster security.

2.14 What is Community?

A Community is a group of people who live in a particular geographical location, enjoying some common properties, facilities and also contribute to the properties and facilities by performing some responsibilities as an individual or as a group. The community includes not only the people living in a certain location, but also the local government, local business sectors, local academic bodies and NGOs. It is common knowledge that the people at the community level have more to lose because they are the ones directly hit by disasters, whether major or minor, they are the first one to become vulnerable to the effects of such hazardous event. Therefore, they have lot to lose if they do not address their own vulnerability. On the other hand, they have the most to gain if they can reduce the impact of disasters on their community. The concept of putting the communities at the forefront gave rise to the idea of Community Based Disaster Management.

The significant of Community based disaster management is the unique way of community engagement on common thought of initiatives for disaster risk reduction. Although government and other NGOs initiated and implemented community level programme before and after disasters but without involvement of community it is useless once the fund is finished. So, Community based disaster way management is therefore very important as communities'

consequences around them to identification of risk, vulnerabilities and mitigation efforts in the community.

• An excellent way of disaster preparedness and coordination will minimize its impacts.

• Maximum lives can be saved during the disaster and after since they are familiar with place and situation.

• The any problems can be solving such as survival and health after disaster can be carried out more efficiently.

2.15 Community Based Disaster Risk Reduction Approach

All development is human ideas and to reduce disaster risk is human action which can create the good relationship with disaster happen and disasters risk. Disaster Risk Reduction thought into development sectors makes good sense in many ways including the following:

• The factor affecting poverty unsustainable modernization and natural and manmade disasters are related who have originate to promote the vulnerability of livelihood and destroy the property of mankind and also affect the development which became concerns of disaster risk reduction.

• Development can bring disasters and disaster can put development at risk by making them unsustainable. We need to invest money risk reduction and preparedness as same as we used to do in recovery and reconstruction.

2.16 The Hyogo Framework of Action

On 2004 Kobe in Japan held a world conference in which global society implemented the Hyogo Framework for Action for disaster risk reduction. The Hyogo Framework came up with five main priorities in order to increase resilience of affected and affecting communities by disasters:

• Make sure that disaster risk reduction will become a main priority for national and a local level with a bold institution basis for implementation.

• Early warning installation, Identify, assess and monitor disaster risk should be there.

• Use innovation, education and knowledge to build a tradition of resilience and safety at all level.

• Minimize underlying risk factors.

• Disaster preparedness should make bold for effective response at all levels at all time.

Community participation and community epicenter for disaster risk management is included in all five parity is the main theme. The Hyogo Framework came up with the relationship between development and disaster risk management in all sectors.

2.17 Disaster management model

Models and schemes help in conceptual simplification particularly in community participation. In the development programme process disaster mitigation and risk reduction gives greatest opportunities for the integration of disaster management. River flood modeling in phuentsholing is the challenging factors since it is too much complicated as natural and man-made flood resilience structures are failed many times. Nowadays we are mainly focusing on modern development Its main intent so our common interpretation tends to deal more on activities immediately before and after the disaster event. Flood resilience model will be adapting in phuentsholing flooding area in order to give strong challenge to flood by building bold resilience structures.

2.17.1 Amochhu river in phuentsholing.

The Phuentsholing town is in a commercially strategic location and also known as trade hub of Bhutan on the Bhutan-Indian border. Capital city Thimphu is the largest city in Bhutan followed by phuentsholing. The location of Phuentsholing city is adjacent to the Amochhu/Toorsa River which is flowing from its steep upstream and join onto the plains fertile land to a width exceeding 1km. in the figure 1 below shows the general location Amochhu river in Chhukha in an aerial view image looking north-east of foothill. The convergence of the Amochhu river is bypass from phuentsholing and enter into Jaigaon the city to the so India followed by river Brahmaputra. The Amochhu River is indeed located in Phuentsholing, a town in the Chukha District of Bhutan. Phuentsholing is situated in the southwestern part of Bhutan, bordering the Indian state of West Bengal. The Amochhu River flows through the town, and it serves as a natural boundary between Bhutan and India.

The river originates from the Chumbi Valley in Tibet and enters Bhutan near the town of Phuentsholing. It continues to flow through the town before joining the larger Wang Chhu River, which eventually merges with the Brahmaputra River in India.

The Amochhu River is significant not only for its natural beauty but also for its importance in supporting agriculture, providing water for irrigation, and contributing to the overall ecosystem of the region.

Figure10 Google earth image of phuentsholing and Amochu

Approximately 3,785sqm watershed area down to Phuentsholing are there as far the research made by Chhukha Dzongkhag in 2015. As shown Figure 2 the catchment area of Hasimara which is approximately 15k away from phuentsholing has 4002sqm.

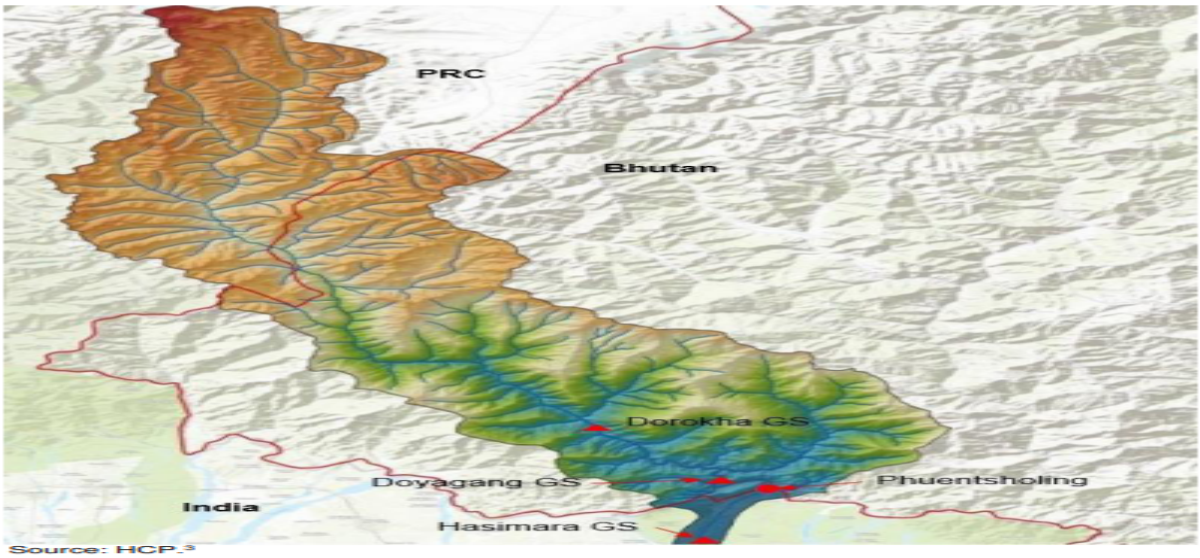


Figure11 Amochu catchment area

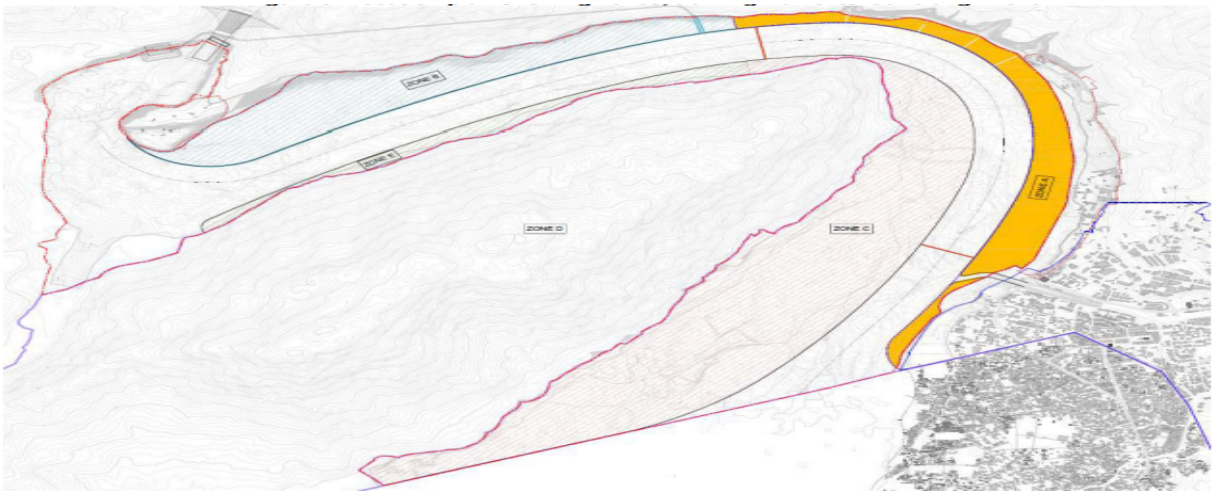
As far the research of 1015 evidence of fluvial flood disaster damage in Phuentsholing are scarce. The flood information written reports given in kennel the national newspaper the maximum observed water level so far and erosion damages many bridges, roads, buildings and vehicles. The floods disaster resulting a huge damage have been experienced in year June 1993, July 1996, August 2000, May 2009, July 2015, July 2016 and so on. Figure 4 shows 2015 event.

Source: DHI-Infra Ltd[13]

Figure12 July 2015 flood inundation and interal erosion damage

Due to the development easy exist of goods the population of city is increases and now area become a problem which giving serious shortage of land for development and expansion. Due to high river current the erosion and cutting of soil is very high which lead to Sedimentation. The uncontrolled river flows given us great challenge which makes us fair and we are losing many valuable properties loss of the city of Phuentsholing.

About 462 hectares of land beside the Phuentsholing city along the Amochhu River had been under development project from 2016 and it was a long-term development project which is funded by foreign government is so called Amochhu Land Development and Township Project. They said that project will be acting as a safe guard from river floods disaster in which construction of smart modern infrastructure to allow phased urban expansion. Town planning and development project will also be benefiting the old area of town from river floods disaster but still riverbank erosion is threatening lives and disrupts connectivity with nearby communities as well. The project is divided into five zone that is from A to E. The allocation of zone and riverbank safeguard has been shown in Table 1 and shown in Figure 5:



Source: HCP drawing BM-PB-01.

Figure13 location plan showing zones, training wall extent and alignment

2.17.2 Climate risk screening

Some of the important topics in Bhutan can be floods and landslides which are rated high in the table below and precipitation raise. Some of the important Town planning and development project events and infrastructure are:

• Precipitation increases: Increase in river flood frequency and intensity may result to impact on drainage and public & private infrastructure.

• Flood: The frequency and intensity of river flood activities may promote cutting, transporting and deposition of soil, emphasize landslide activities, damage to drainage systems and surface flooding.

• Landslide: as landslides increases the activity of sediment transportation will increases and due to debris, the river training structure can't resist its pressure which conveyance problem for cross drainage facilities.

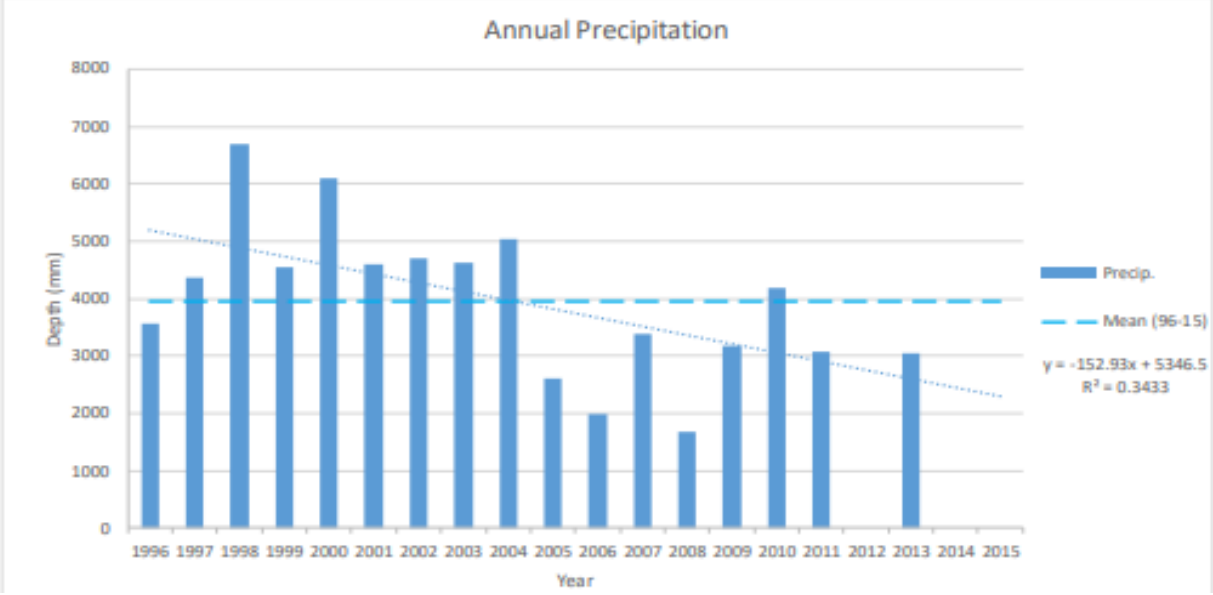
Risk Topic	Project
E) Precipitation increase	
F) Flood	
G) Snow loading	
H) Landslide	
I) Precipitation decrease	
J) Water availability	
K) Wind speed increase	
L) Onshore Category 1 storms	
M) Offshore Category 1 storms	
N) Wind speed decrease	
O) Sea level rise	
P) Solar radiation change	

Source: PPTA Consultant adapted[22] from AWARE analysis

Table5 PPTA analysis

2.17.3 Impact Assessment

In the figures 8 shown below the previous recorded yearly precipitation b/w 1996 and 2015 for Phuentsholing. The average of bar graph shown the linear trend line. In x-axis the numbers are shown for yearly bases when there are thirty recorded during the monsoon season and in y-axis it shows depth of flow.



Graph1 phuentsholing precipitation

2.17.4 Vulnerability Assessment

As far the previous record Phuentsholing city has recorded maximum rainfall in which fluvial floods from the Amochhu is a threat to livelihood of the city as well as landslides and debris

flows which increases intensity so the pressure is automatically increases. But data is not well preserving and save and now it is not well documented. Although government has stopped and not anchorage any development activities in open areas. Figure 15 shown below is the north of Phuentsholing where river Toorsa/Amochhu hitting the city most.

As shown in figure 16 the damage seen on construction of a river flood defense scheme which is initiated in 2002/2003 where it is funded by ADB-financed. The location of the Amochu river defenses system and sewage treatment plant can be visible.

Source: PPTA. Annotated Google Earth image dated 19/12/14.

Figure14 location plan

2.18 Summary of Selected Important Publications Related to river flood disaster

Phuentsholing township development project disaster and climate risk and vulnerability assessment May 2018

This article mainly recorded the Disaster, Climate Risk and Vulnerability in Phuentsholing Township Development Project. The hazards included earthquakes, flood and landslides in the city. The climate change is the main consequence and it will bring huge risks which included increase in frequency and intensity of river flood disaster events and maximizing intensity and frequency of rainfall events enhancing to raise in frequency of river flood disaster in the city (DHI,2018). The Toorsa river is all the way flowing from China followed by Ha, Samtse and finally Chhukha before draining in Brahmaputra of India. The above catchment area of its river is at a higher elevation with gorge slopes.

The starting point of river Amochhu is Mount Pauhunri 7,128m above the sea level. From the source to phuentsholing is about 3,785 km2.The climate of phuentsholing is humid and located at subtropical region in the southern foothills. Phuentsholing city is located at very low altitude of 220 m from the plain of India so call Assam. As measured by meteorological recording point at Hasimara and Jalpaiguri it's have approximately 24 ºC in both recording stations (DHI,2018). All the warming data is scattered in the upstream catchment area in Bhutan; but the changes can be expected to be higher. 4,880 m high altitude which share border with China which remains always snow cover since it has been experiencing zero temperatures throughout the year.

2.18.1 River flood modeling of Amochhu river using GIS: a case study in phuentsholing city, Chukha, Bhutan.

Phuntsholing became the research area for many researchers because is it frequently attack by the river flood disaster since from long time back and also a main commercial hub of Bhutan for international trade. The city is many times washed and damage by river flood although our government and other NGOs frequent rebuilding its destruction. It is recorded that flood modeling in Amochhu river help to come up with the very good map in order to map the affected and vulnerable people around Phuentsholing (Rahman, 2014. In this article authors mentioned that Log-Pearson and Log Normal III techniques is adapted in order to find out the numbers and places where maximum people got affect in that particular location city in present and in future. But as far his perception the log normal technique seems to be more useful in the rapid changing city like Phuentsholing. As far the research recorded data result the phuentsholing shows that the major risk and vulnerability by river flood in monsoon season from last twenty-five years one thousand years (Teng et al, 2017). The previous research also shown that the city will be divided into different zones such as Zone B, Zone E, Zone C are the vulnerable places followed by Zone A. it is also mentioned that the depth of river getting increase day by day.

As we all know that Flood is natural occurring disaster which can cause vast distraction in the flood prone zone by its extensive inundation (Teng et al., 2017). Due to the overflow from channels such as natural river because of assistive downpour, sea and others large natural water basins which is acceleration by mixture of wood, stones and soil high steep regions or due to saturated rainwater in the ground which can create aerial flood (Rahman, 2014). The problem of river floods disaster it is direct or indirect can taking lives, properties damages, environmental degradation and the damage on cultural heritage. It can also disrupt the casual life of huge population in phuentsholing and their activities (Teng et al., 2017). The natural

river Floods in phuentsholing can causes by two factors that are heavy rainfall and human factors in which we block the natural channel due to modern development. Growing in populations and modernization all-natural structure cut off and land with higher river flood proximities became much more prone to runoff because of involvement of human activities. On top of that flood is becoming more life-threatening if climate change involves with socio-economic damage (Tingsanchali,2012).

2.18.2 Final Report on Installation of Interim Community Flood Early Warning System at Amochhu, Phuentsholing

In this article it is mentioned that installation of warning system for flood disaster in Amochhu river for flood security is commanded by His Majesty to southern COVID-19 Task Force in phuentsholing to offer good early warning of river flood disaster for people who are settling in the shelters under construction temporary on the Amochhu river side. After then His Majesty the king direct command the upper level COVID-19 Task Force started seeking information from national center for hydrology and metrology to install the river Flood Early Warning System. The formed agency started managing and working with full preparation and planning to put the river flood early system by adjusting with materials in the market. National center for hydrology and metrology shared the designed and plan of the famine early warning system on 23rd April 2020 to the High Level COVID19 Task Force in Phuentsholing city. National center for hydrology and metrology came up with six Technical Teams with expertise to come up with the installation work which is held on 26 April 2020. After that the teams are immediately deputed to site (NHCM, 2020).

2.19 Flood hazard assessment for Chukha dzongkhag

The earlier research recommended that the permanent installation of rainfall measurement stations in phuentsholing geog periphery will provide more resent hourly data which is very important to see the pattern of rainfall over the short time on Amochhu River catchment in the city. But further study is required to do proper research on this location to select the best techniques for rainfall reader, estimation installation of early warning system. The research also comments that required data saver equipment and recorder machine which should be install on a location by plotting the map on above hill side where it is suitable to acquisition data. The whatever work are done by national center for hydrology and metrology accompted with covid-19 task force will be only river flood management plan and model design. And this data and groups will not work for its own or administrative purpose so this agency will give his full concern on one particular work (Chhukha,2011).

2.19.1 Flood Early Warning Systems in Bhutan a Gendered Perspective

Drukyel had experiences of frequent water related disasters. As far the population of our country we are ranked in the fourth position in place of flood exposure Asia-Pacific region. According to resent research by national center of hydrology and metrology approximately 1.7% of its total population exposed to flood risk (NCHM,2020). As we all know that climate change Tigger the frequency of rainfall and risk severity of flood disasters in Bhutan from long time back. Bhutanese people are suffering during monsoon season because of Inequalities downpour which openly amplified the river flow current increases times that of normal flow which cause huge disaster and makes people living in hunger specially the elderly, children and women are particularly vulnerable to flood hazards (NCHM,2020). This article is also encouraging to install reliable river flood early warnings system that is the needs for both women and men. The Early warning systems will be people oriented, accurate, reliable and data acquired from it is understandable to communities at time of risk or before and after and that emphasis the right action to be taken by vulnerable communities can save people more effectively (NCHM,2020).

CHAPTER THREE

Methodology

3.1 Research Design

River Flood disaster is one of the most dangerous natural disasters in Bhutan. River flood disaster is outcome of climate change and global warming. We can clearly see that rising of sea level, increasing temperature and seasonal changes can contributing natural disaster. River flood disaster is being taken as serious problem and options for adaptation are being implemented. City under the thomdee (sub district) regulation is taking this disaster as a primary focus of attention in disaster risk reduction of flood and giving more attention in monsoon which is affected by disaster which is more importantly responds to the event (Russell Dynes,2011). By looking at the above fact the topic was selected to elaborate one of major river flood disaster through community base disaster management in collaboration with government and non-government organization. The research work is started by making good research on literature review and a draft questionnaire to test in the field or on online bases due to present situation in prior of survey. Also come up with some of the related models which can help to explain conceptual simplification in river flood disaster in phuentsholing as of now. The model used in Disaster Risk Management Cycle and Disaster risk reduction can also include in this paper. This proposal is discussed with focal personnel in the affected area and

local stakeholder who are staying nearby and have a good knowledge on this disaster which can help me to plan the fieldwork in right manner. Whatever data is collected it during the online/field visit will be recorded in Participatory urban Approaches.

3.2 Research of relevant literature and information.

To have a good and better knowledge of the river flood disaster and community base disaster management study the important previous report and other related paper will be reviewed. In order to get clear idea on river flood understanding the existing disaster risk management relevant model such as Disaster Risk Management Cycle and Disaster risk reduction models. For the good outcome of the secondary data information collection the climate and river flood similar data like temperature, rainfall and meteorological data with the help of research study from Department of mines, geology and Department of Disaster Management.

Phuentsholing is a border town in the southern part of Bhutan, located at the foothills of the eastern Himalayas. The town is situated at the confluence of two rivers, the Toorsa and Amochhu. The Toorsa river flows from Tibet and passes through Bhutan, while the Amochhu is a tributary of the Toorsa. The town has experienced several floods in the past due to the overflow of these rivers.

There is limited research on the floods in Phuentsholing, but some studies have been conducted to understand the causes and impacts of flooding in the town. One such study is "Assessment of Flood Risk in Phuentsholing Town, Bhutan," by Kado Zangmo et al. (2019), which assesses the flood risk in Phuentsholing and identifies the factors that contribute to flooding in the town. The study used GIS (Geographic Information System) and remote sensing techniques to analyze the topography, land use, and rainfall patterns of the town. The results of the study showed that the main factors contributing to flooding in Phuentsholing are topography, land use changes, and climate change.

Another study is "Flood Risk Assessment of Phuentsholing Town" by Tshering Gyeltshen (2015), which analyzes the flood risk in Phuentsholing using GIS and remote sensing. The study identifies the areas that are vulnerable to flooding and recommends measures to mitigate the flood risk. The study also highlights the need for improved land use planning and management, better flood forecasting, and early warning systems to minimize the impact of floods in the town.

Additionally, the Bhutanese government has undertaken several measures to reduce the risk of flooding in Phuentsholing. These measures include the construction of flood protection walls along the Toorsa and Amochhu rivers, the relocation of vulnerable communities, and the implementation of land use regulations to prevent construction in flood-prone areas.

In summary, while limited research has been conducted on the floods in Phuentsholing, the available studies highlight the importance of understanding the causes and impacts of flooding in the town and implementing measures to mitigate the flood risk. The Bhutanese government has taken steps to address the issue of flooding in Phuentsholing, but more research and efforts are needed to ensure the safety and well-being of the town's residents.

3.3 Selection of Study Area

River flood disaster in phuentsholing is chosen as a study area to study the lack of resilient structure in the city where Toorsa chhu along phuentsholing city under Chhukha dzongkhag. Almost all the city periphery in the maximum population settlement is settled on a bank of river Toorsa chhu. This population already experienced many river flood disasters every year from long time back. Ultimately, the research study chosen will depend on the research goals, available resources, and the interests and expertise of the researchers involved. Some potential research study areas related to flood disaster are, flood risk management, flood warning and preparedness, flood mitigation and adaption strategies and social economic impacts of flood.

3.4 Geographical Location

3.5 Chhukha Dzongkhag is in southern part of southern Bhutan which had 11 gewogs and more than 50 villages. The phuentsholing geog is located in southern part of Chhukha dzongkhag and has an elevation of 293 meters above the sea level as shown in figure below. The closure of a geographical location for research can occur due to varies reasons such as political instability, safety concerns, natural disasters or legal restrictions. Ultimately, the decision to proceed with research in a closed geographical location should be based on careful consideration of the potential risks and benefits, as well as the ethical implication of the study.

3.4.1 River system

Phuentsholing Geog is located along the bank of Toorsa/Amochhu. And the original sources of Toorsa chhu is from China where they called as Machu in Chumbi valley in Tibet region. Amochu had got three tributaries at sources mainly the Tangka chhu, Khangphu chhu and Toorsa which all are flowing south. After entry of Machu into Bhutan from China it is known as Amochhu or Toorsa which is finally get into Brahmaputra to Indian ocean.

3.4.2 Past History of river flood disaster

Bhutan had experienced river flood disasters in southern part of the country in summer because of almost all the rivers are flowing from this region. These places are frequently facing river flood disaster every year since these places are located in southern plain with maximum population. From 2016 to till date we have at least some data but before that we don't have data in river flood disaster. It is recorded that 2016 river flood disaster is most deathful disaster in the history of Bhutan (Leber et al,2003).

3.4.3 Seismicity

Many rivers in Bhutan are originated from lake and have many dams in Bhutan and if Earthquake hazard hit than almost all the southern boarders will be flooded. Bhutan has a different zoning system of earthquake in which western Gard zone four and Eastern Gard in Zone five are very risk. For the first time, Hazard zone is drawn as shown by the Indian institute of technology.

As of now we don't have river flood disaster in Bhutan which is came after the action of earthquake hazard. But on 21st Sep. 2009 we had an earthquake magnitude of 6.1 which claimed twelve live in Mongar and Trashigang Dzongkhag and many got injured due to collapsed buildings. Lots of buildings and roads have been damaged. But now due to climate change and modern development all-natural structure become very week so if such disaster happens, we are very much vulnerable to river flood disaster in future specially in southern boarders. River Toorsa is flowing from China and its sources is about to burst out if such earthquake disaster is occurred than all the down are get wash away. So, this area needed ongoing monitoring and assessment of the seismic hazard in the country to ensure that building and infrastructure are resilient to potential earthquakes.

3.4.4 Communications

The study location is interconnecting with mega highway since it is located along the city so it does not give any problem for travel. As it was along the city it is very easy to communicate because 5g is connected everywhere. Overall, effective communication during a river flood in critical to keeping people safe and minimizing damage to property and infrastructure. It is essential to have clear, accurate, and timely information communicated through multiple channels to ensure that everyone can respond appropriately to the situation.

3.4.5 Vegetation and Land Use

As the study location is in southern plain and along the city which have limited vegetation and agriculture too. The place is under town planning which is adjacent to the main town also known as trade hub to international market. The modern development is threat to natural vegetation in and around the phuentsholing. It can play important role in reducing the risk of river flood disasters and improving the resilience of communities and ecosystems. However, it is important to consider local condition and consult with experts to determine the most appropriate vegetation strategies for each area.

3.5 Reason for choosing this phuentsholing river flood disaster study area

1. The past river flood disaster events which started from long time back in the city.
2. This river flood disaster has impacted many people in the city very badly.
3. No single research had written the paper on the regard so it is very much challenging for me to write this paper.
4. The river flood disaster hamper the socio-economic development such as tourism, transportation and sustainability as well as huge losses of lives of people.
5. And also it is importance, relevance, interdisciplinary nature, practical application and global impacts.

3.6 Source of Data collection

Data collection is one of the important criteria for any research study and gather the data. To collect data, analysis it and management can play paramount role in research work. The sources of data in this research study are of secondary data and primary data. PAR method is used to collect primary data in online interview and to assess the present impact, Risk, vulnerability and livelihood of city is guided by satellite data. The change in temperature, glacier melting on high altitude, rainfall status, some government recorded documents, meteorological data and other published and unpublished information as a secondary data.

If situation favored me, I may collect valuable data on river flood disaster at phuentsholing city from the people who observer the real drama in the summer. I am not able visit the study area physically but I did online interview with many people living in the city. City people are well aware of structural and non-structural mitigation measures from Thomdee and Dzongkha Disaster Cell by keeping the city in high alert during monsoon. I had online conversation with Bhutan disaster management organization and other high-profile people to get good existing

information on river flood disaster in phuentsholing city and also got little information about Chronology of the flood, installation of early warning system along the city and to find out the of evacuation center if flooding happens. The most recent update I got is that river training structure are in the way.

3.7 Satellite Data

Study area doesn't have much resource materials but had some highly magnify image regarding river flood disaster in the city. I did not find any satellite data regarding data river flood disaster in Phuentsholing since there is no such data due to technology limitation.

3.8 Selection of site for PAR

The research work is carried in periphery of phuentsholing city in Chhukha Dzongkhag. Phuentsholing city is located along the bank of Toorsa/Amochhu river on the terrace of 3m to 4m above the river. Almost all the structures made by people are permanent as it was trade hub for international trade. The study area is selected after the discussion with my dissertation supervisor by keeping in mind that the place is highly affected by river flood and no initiative is taken for resilient structure so far. Some key consideration:

1. Accessibility: The site is easily accessible for all stakeholders, including government officials, reliefs agencies and affected communities.
2. Proximity to the disaster zone: the site should be located close to the disaster zone to enable quick response and communication during emergency.
3. Infrastructure: The site should have adequate infrastructure, such as electricity, internet connectivity, and communication facilities.
4. Visibility: The site should be visible and easily identifiable by all stakeholders.
5. Availability of resources: The site should have the necessary resources, such as staff, equipment, and supplies, to support effective reporting and accountability efforts.

6 Collaboration with local communities: The site should be established in close collaboration with local communities and relevant stakeholders.

Data collection methods

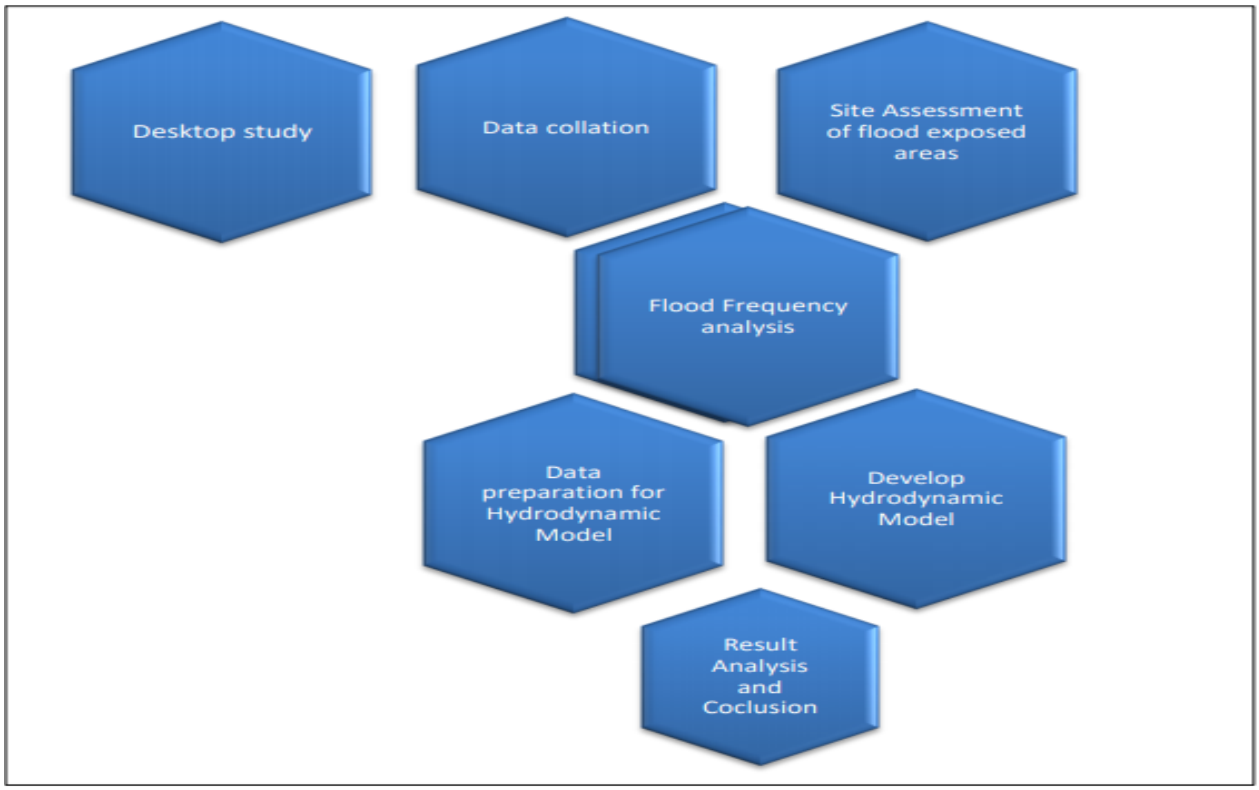


Figure16 Data collection method diagram

3.8.1 Report from local level stakeholders

First of all, meeting was organizing with local level stakeholders who have live experience on the study area and also, I shared the reason of selecting the study area as my dissertation topic. It had such a meaning to come up with the such type of study location since it is first time I am researching on this topic.

3.8.2 Interviews or a group discussion

The interview is scheduled which consists of questions from 1-5 steps. In question first step I included general questions to seek information on geographical and demographic characteristics of study area from the local and official of city. In second steps I included question on social mapping in which I designed questions to solve conversation to have good picture about the city and its development. In third steps I raise the question on vulnerability to check vulnerable population and its issue where city can easily understand the statistics ranking. In fourth and fifth steps I tried to seek knowledge from the respondents about river flood disaster and risk perception in the study area. Also, I had questions on awareness on

global warming and climate change. I also gather the information from government and NGOs by having group discussion on online mode.

3.9 Data Analysis Procedures

The research is based on quantitative study on river flood disaster and needs of resilient structure in the flood prone area. Vulnerability and risk analysis on phuentsholing city of Chhukha Dzongkhag through field study is more qualitative in nature. In the end of the research paper, I will add some recommendations for future reference of the study area.

When analyzing river flood disasters in Phuentsholing, a comprehensive approach is typically employed to understand the causes, impacts, and potential mitigation strategies. Here are some key data analysis procedures commonly used:

1 **Data Collection**: Gather data related to river flow, precipitation, topography, land use, population density, and infrastructure in Phuentsholing. This data can be obtained from government agencies, meteorological departments, river gauging stations, satellite imagery, and census records.

2 **Historical Analysis**: Examine historical flood events in Phuentsholing to identify patterns, frequencies, and severity. Analyze past flood records, including river discharge data, rainfall measurements, and damage reports, to understand the dynamics of flooding in the region.

3 **Hydrological Modeling**: Utilize hydrological models to simulate river behavior and flood patterns. These models can incorporate factors such as rainfall intensity, terrain characteristics, land cover, and river channel capacity. The outputs of these models can provide insights into flood potential, flood extents, and flood durations under different scenarios.

4 **Vulnerability Assessment**: Assess the vulnerability of Phuentsholing to flood events by analyzing factors such as population distribution, infrastructure exposure, and socioeconomic conditions. This assessment helps identify high-risk areas and vulnerable communities that require immediate attention and appropriate mitigation measures.

5 **Risk Mapping**: Develop flood risk maps that integrate information on hazard (river flow, precipitation), exposure (population, infrastructure), and vulnerability. These maps provide a visual representation of flood-prone areas and assist in prioritizing mitigation efforts, emergency planning, and land-use decisions.

6 **Socioeconomic Analysis**: Evaluate the socioeconomic impacts of flood disasters in Phuentsholing. This analysis involves assessing damage to infrastructure, loss of livelihoods,

disruption of services, and the economic implications for the affected population. Quantifying these impacts helps prioritize investment in flood protection and resilience measures.

7 **Stakeholder Engagement**: Engage with local communities, government agencies, and experts to gather qualitative data, understand community perceptions and experiences, and incorporate local knowledge into the analysis. This participatory approach ensures a comprehensive understanding of the flood disaster context and facilitates the development of context-specific solutions.

8 **Scenario Planning**: Use data-driven scenarios to assess the effectiveness of various flood mitigation strategies. Simulate different flood scenarios based on potential interventions, such as the construction of flood control structures, land-use changes, or early warning systems. Analyze the outcomes of these scenarios to inform decision-making and prioritize risk reduction measures.

9 **Long-term Planning**: Develop long-term flood management plans and policies based on the analysis. These plans may include structural measures (e.g., embankments, flood walls), non-structural measures (e.g., floodplain zoning, land-use regulations), early warning systems, and capacity building initiatives. Ensure that the plans are adaptive and account for future changes, such as climate variability and urban development.

It's important to note that the specific data analysis procedures may vary depending on the available data, expertise, and resources. The aim is to develop a comprehensive understanding of the flood disaster context and inform evidence-based decision-making for effective flood management in Phuentsholing.

CHAPTER FOUR

Result and Discussion

4.1 Social Mapping

The Phuentsholing city is three and half hours' drive from the capital city, Thimphu broader of Jaigoan, India. The city is satiated along the river Toorsa/Amochhu. Curved land with loose soil which is main international trade hub of the country. The city is interconnected with high way and express way in order to supply all type of goods to export and import. During rainy season it makes difficulties to drive and park the vehicles as it received water from everywhere since it is located at the bottom of the country geographical location. The good point of the city is that it has rote to go every part of the country without any difficulties. Socio-economic situation of the people living in the city is not that much weak since almost all the people are with small self-sufficient job. Most people living in the work in office and business and all of them are self-sufficient, happy before covid-19 but after virus break out everything changed since lockdown from 2020 till date (Ran Bdr chhrttri,2022). The main earning sources are from business and office work and also from construction work as Bhutan is getting into modern era. All the needed materials are available in the city with minimum cost and highly durable.

The city is well organized and have good sanitation facility since it is having twenty-four hours water supply from the fresh water sources so called natural streams which is supplied by the water supply authority of phuentsholing. Every household in the city is connected with water system facility so call pipeline. Sanitation facility in the city is hygienic as far the health view point, since all the household have their own toilet and none of the people in the city I found without good toilet. The city has many children care center, many primary, lower secondary, middle and secondary school where every child of city is easily be in the school according to their standard and city has one nursing college which is private and engineering college which is government. In Bhutan education facility is free till the master degree if the child is intelligent to secure the seat and because of this facility no children are deprived from education. The city remains calm in the day time but rush in the morning and evening since all the young people so call students rushing to schools and colleges in the morning and roaming in the city in the evening. In phuentsholing city most of the houses are made up of concrete structure comprise with cement, sand, aggregates and steels and wood with CGI roof which is resilient to flood for some extent but due to poor drainage system we can't say that our present structures are flood resilient. And none of the structure in the city are semi-permanent structure such as house

made up of wood and mud. And few houses and shops are semi-permanent structure made of wooden plank and tin sheet as roof.

And most of the concrete structure in phuentsholing city are vulnerable to river flood as they are recognized as red zone. In some conversation, I asked the why you love to settle in the flood prone area and their answer is same as it is one of the best places to do business as it is trade hut to international boarder. Also, they told me that it is chill in the winter and hot in summer and some of them love to stay in hot places due to their medical issues. Phuentsholing city has one referral hospital after Thimphu and Mongar so most of the patients can get good health services and treatment. Communication facility is good in the city both in summer and winter season as there is 5G connection recently with excellent road facility. The major transportation facility are city bus, taxi and private vehicles for people travel and for goods transportation we have truck, tipper and etc. There are three-evacuation places are identified by Thomdee if it is attack by river disaster at any time.

4.2 Resource mapping

A map which can shows the details of entire city area mostly natural resources and the present human mobilization. Resource mapping gives us lots of idea to design map of natural resources as well as resilient structure, whichever is used as livelihood assets in phuentsholing city. The mapping is done by taking the help from satellite phased array type l-band synthetic aperture radar 12.5m is resampled into digital elevation model 5m spatial resolution to facilitate the simulation in the study (NCHM,2018).

4.2.1 Human Capital

City of phuentsholing well aware of river flood hazard and they are well adapted themselves since people had experience on many rivers' floods event as of now. The Human capital in phuentsholing city is carried out by the different occupation types as mention below health, education, house structure, Skill and Knowledge enhance facilities. In phuentsholing city there are many primary and secondary school and colleges which are their main sources of education institution. In which all class people can happily pursue their education whether from formal or non-formal way. And many schools are also used as river flood disaster shelter since they are little elevated from river bank level. All schools Building structure are concrete structure and it's don't have much danger of river flood hazard until and unless landslide and cutting of soil not take place. Phuentsholing city have good health facilities for all national and international patients with the theme of equality. Health care team is sent to evaluate sanitation and other health issues. In the city, most of building structure are built with rcc and tin.

4.2.2 Natural Capital

As business being main income of livelihood for phuentsholing city from where all the goods distribution is done since it is also called city of international trade. So, because of this piacular reason people are do their business as far their convenient and season. In the interview and discussion many people says that they are always praying to the god that river flood disaster will not occur again in the city. If happen so many people not only lost their property but also the precious life. Due to the human migration and modernization all-natural structures are totally destroyed which shows us there is need of river flood resilient structure. They used to get all business goods from Jaigoan, India.

4.2.3 Social Capital

The Social relations in and around the city is very good. In phuentsholing city neighborhood relationship is extremely good as they trust each other to do business as their requirements. Helping each other is their good did in the times of building shelters and houses before and during the time of disaster. By looking at the present scenario it clearly shows that city people really helped each other's in term of labor and financial needs. Government also helps to provide social resources. In order to minimize river flood disaster government also increase the work forces training and budget as well. Mock drill Help people to reach them safe place during and after the flood. Both government and non-governmental organization are actively participating with community to reduce the risk of river flood.

4.2.4 Physical Capital

As we see the location of phuentsholing city it is vulnerable to river flood disaster, as we also see the river flood training work is ongoing in and around then flood prone area but it shows that this structure will only reduce the loss. And the rote the evacuation site well executed high way for evacuation support during and after the disaster. In the flood prone area, it is said that time for evacuation will be much easier since they have installed the early warning system and it will provide information regarding raining fall a day before. In the town there are many evacuation centers, which are all high elevated schools. The Location of the city is just at the bank of the river Toorsa, where all building structures are made up of very strong materials such as steel and concrete. And it is so called permanent structure but when water enter into the city because of its soil eroding capacity building will makes upside down. The city is strongly having its way to information system in which both radio and television provide them important information/notice. It is seen that all room has one radio, television and mobile phone. The energy source in the city is electricity.

4.2.5 Financial Capital

The people of phuentsholing city are not so poor and every one had bank saving on individual's account. All most all the people in the city are businessmen. They do business, government and non-government job which makes them rich, and they built building and people without gob they don't have quality house to defense any natural disaster. All most all the child from the city are studying in government and private colleges in which all the expenses are made by doing business.

4.2.6 Observation after resources mapping

Just after the resources map was done, I came to know that all the resources city needed is that evacuation centers as well as natural vegetations is necessary in all over the city in order to tackles the river flood disaster in summer. For time being Thomdee should come up with some others techniques to do quick evacuation without disturbing ongoing classes in the school. Another important observation is that by knowing the risk of river flood disaster people used to build house near river bank and want to establish business, the government should provide necessity requirement as they needed or not entertain them to settle there since all the town development area is consider as red zone. As river flood disaster is natural and we can't stop natural hazard completely.

4.3 Vulnerability assessment

The term vulnerability never be same for same society or different society as geographical location differ for every place in same location because of their level of vulnerability might be same or different so people of that society have less capacity or more capacity. By looking at the scenario we can identify the opportunity to face hazard but if that hazard is turned into disaster than everybody is vulnerable. Vulnerability does not mean for rich or poor but it is vulnerable if people fell, they are not safe and secure. Phuentsholing city is one of most vulnerable place of river flood disaster. This very city had already experienced many disasters hit by river flood event since from many years back which claim many live as well as property. and causes huge loss to its livelihood. At the of my field visit in the phuentsholing city I have gone through the vulnerability of the city and also their livelihood pattern.

4.3.1 different approaches for vulnerability assessment

4.3.1.1 Flood plaining

In flood planning stage we need to ensure the information of infrastructure, land use planning, forecasting of flood and flood vulnerability are good.

4.3.1.2 Flood preparedness

In this stage we need to check coordination and individual responsibilities, regular inspection calculation of materials needed and identification of safest places.

4.3.1.3 Flood fighting and post flood operations.

In this stage we need to regulate and protect flood flow, and make a rescue and relief operation as far as possible together with resettlement. At the end damage, restoration and recovery is out most.

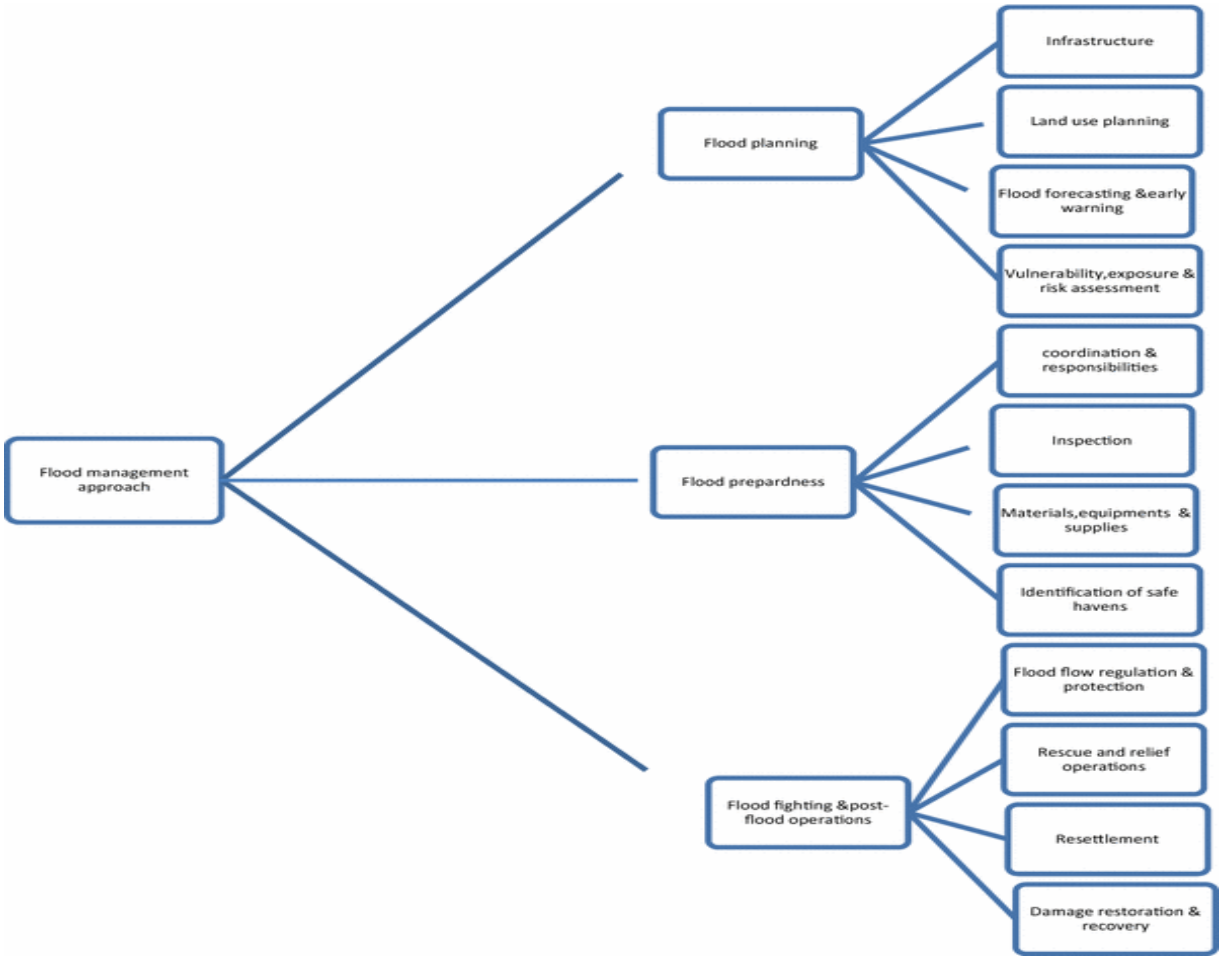


Figure17 Vulnerability Assessment

4.4 Type of Vulnerability

There are many terms and conditions on vulnerability such as physical factor, social factor, economic factor and environmental factors. This factor can maximize the susceptibility of particular places to overcome hazards since it can adversely affect the ability of people to prevent, prepare, respond and mitigate the hazards. Vulnerability also consists of five resources which can go under any situation. All the damages and lost loss will be asses based on the resources which are indirectly or directly under danger when disaster occurred. To five resources of vulnerability are given below:

- Economic resources vulnerability
- Physical resources vulnerability
- Human resources vulnerability
- Natural resources vulnerability
- Social resources vulnerability.

4.4.1 Social resources Vulnerability

The term social vulnerability refers to demographic and social behaviors of household structure and the community as a whole (ref). The base level capacity of river flood risk management can be carried out on base of family income and livelihood support, preparedness plan and usual practices. In phuentsholing city, the regular flooding as recorded from 2016 are the much devastating not only in terms of structure but also in livelihood base in the flood affected area. The reason behind this devastating event is that there is no proper guidance and assistance for flood resilient structure in the past and present but we as a young youth need to think what will be its solution for river flood disaster in Amochhu river. As of now there are two types of early warning system namely automatic and manual early warning system. Although automatic warning system give accurate warning but sometimes it is failing to give eject time since many people don't have faith. People don't have faith and trust on early warning system so we need to educate them as it is very important.

4.4.2 Human resources vulnerability

As far the disaster data of united nation development program the frequency and intensity of natural disaster has been maximized in few years (UNDP, 2004). As the population in the city drastically raised there are so many people who get settled in the flood disaster risk area. Because of this reason the vulnerability of livelihood is raised due to unsafe construction practices in and around the flood risk area.

4.4.3 Economic resources vulnerability

Economic resources in place of river flood disaster includes lives, infrastructure, public and private properties and livelihood care able institutions. As refer to the previous record most of the infrastructure are built in red zone area where none of the area is safe and secure from flood disaster. Because of this reason many live and properties are being lost. Now huge town planning development program of going on and if such disaster repeat, I can't imagine what will happen. If the existing structure not able to resist the pressure of river there will be huge disaster in future. Some people who had settle there from long time got land from government and also purchased their land and also build house, this people are consider as an economically rich. The people who had settled there from long time back but not able to get land ownership moreover they are with temporary structure which are not resilient to any disaster. Additionally temporary structure build by government are at risk position since they are build up with plywood and wood.

4.4.4 Natural resources vulnerability

In 2000 river flood disaster is the most devastating in that city where most of the houses and livelihood are affected. Many people said that it is happening due to deforestation and development process which can help in soil erosion.

4.4.5 Physical resources vulnerability

Unlike other resources of vulnerability physical vulnerability is mainly draw the attention on commercial area since city is located just beside the river bank. And another small river is in between the city, when rain fall is more the small also get big in the same time big river block the small river which have no option to get into the city. Due to such blockage small river so called Duti wash away reinforce bridge twice.

4.4.6 Observation after vulnerable assessment

The observation made is that there are many infrastructures and factories installation nearby river which are threaten to river flood disaster and this all are permanent structure and can't be shifted. Since it is a trade hub to international world it is not rule and regulation to build house. Moreover, shifting people is more complected than the come up with resilient structure.

4.5 Effectiveness of early warning system

During the interview with the people living in the city many people told me that they feel that river flood disaster event is happened due to heavy rainfall over northern and southern country region and few believes that it may happen due to snow melt on its source due to climate change.

4.6 Observation on Indigenous Knowledge in community base disaster management.

In phuentsholing city there are many Communities Based disaster Management internships and workshop came into place in order to give awareness of river flood disaster and many NGOs are aware so helping the Vulnerable people and making them clear on climate change and global warming as well as on environmental degradation. Afforestation, land-use management and watershed management criteria since it will give knowledge on climate adaptation as well as in risk reduction measures.

4.7 Expansion and contraction model

This model shows that the all-disaster management whether it is natural or manmade processes are continuous. All the activities are running each other in parallel way and they never go in sequence order. Each and every activity can change its way in terms of disaster whether it is natural or artificial/made.

4.8 Prevention and Mitigation measures

This model activities prevent maximum avoidance which can cause adverse impact on environment and livelihood and it's also play important role on biological, environment and technological hazards/disasters (UN/ISDR). In terms of mitigation measures building and developmental activities come into act to minimize manmade as well as natural hazards/disasters which can help in environmental degradation (UN/ISDR).

4.9 Preparedness measures

The way of dealing to such hazard is till challenging now and will be challenging in future too in spite of huge expenditure made by government and others NGOs for effective response together with the issuance of early warning system and evacuation places to save livelihood and property (UN/ISDR). Some of the preparedness programs/activities are to come up with river training wall and high raise building which are not prove to be as good as the flood resilient structures. Relocation and temporary shelters centre are adopted by community and Dzongkhag for the people who are vulnerable to river flood in Phuentsholing city. Plantation of trees are also becoming practices in the prone area.

4.10 Recovery and rehabilitation measures

It is a process of coming back from maximum affected point to the normal point. That means the action taken after the particular disaster hit over a particular place to helping each other's to reduce further risk by providing first aid and immediate ambulance services (UN/ISDR). Individuals are busy in plantation which can reduce hazards and they will also earn by doing that. In place of river flood disaster city don't have good evacuation centre for the affected people due to that loss of livelihood and property go up. During my conversation with people,

they told me the government and NOOs are actively engaging in preparedness activities but people are not happy with the river resilient structures although they spend huge amount of money.

4.11 Live Experiences with river flood disaster

Mon Bdr Chhettri of phuentsholing Geog under Chhukha Dzongkhag of age 71 now and 49 in 2000 physically witness the flood in phuentsholing. On august 14th 2000 after the heavy rainfall across southern boarder led to huge disaster as after long heavy rainfall. As far his comments he told me that the stream flowing through the city is blocked by the big river so call Toorsa so that the swollen stream penetrated into the city by causing huge loss. He also told me that many vehicles, goods and buildings were wash away In-front of his eyes and many people got injured. He also explained that it couldn't be huge destruction if there is early warning system and at least little resilient structures like today. As far his estimation more than one billion U.S dollar loss is happened during that flood. He safe his life by running away from his room with family without belonginess and he did not find his belonginess after disaster. He also claims that he never saw that much inundation in his life so far.

Karna Bdr Chhettri now 47 years old, experiences river flood in phuentsholing in 2004 when he was 19 years old. On 2nd July with heavy rainfall in and across the country phuentsholing city again hit with another flood disaster. At the noon on 2nd July the inundation flow reached

maximum which penetrated into the city by breaking the river training wall. Although he stayed above the city but he watched live what river flood did on the city, with his eyes. Another big river flood disaster hit in phuentsholing on 2004 had made more destruction as many new vehicles and new design building had been washed away. He watches live how vehicles and property got outside down during that flood and he even say that human victim also had happen but not sure how many of them wash away in that event. According to him many animals like cows, pigs and other stray dogs had wash away Infront of his eyes and property destruction is double as compared to previous one.

As far him in this flood although there is drastic change in evacuation and early warning system there is still limitation of resilient structures in and around phuentsholing.

Chanda 63 years old and was 57 is the live victim of 5th June 2016 river flood disaster in phuentsholing and main causes of this flood is due to heavy rainfall for more than a week. According to Chanda he is working as a businessman in phuentsholing and had wholesaler shop in lower market of core city. All the swollen water from river Toorsa enter the city by breaking the stone river training wall which even wash away goods from shops. He and his family has been successfully evacuation from the victim place since early warning and evacuation facility drastically improved but he also recommends of needs of resilient structures in the city in order to stop such disaster. As far his thought the township program in the city is more engineered and well-designed, the river training structures are not up to marks so if Toorsa river get into the new ongoing town planning area than situation will be worse than ever. Sometime our urban planner forgets to include all these important points in planning which give us long term effect. City planning is outstanding, and it will be one of the biggest cities in our country after the completion but if we not give more concerns on river flood resilient structures than heavy losses on live and properties in near future as far Chanda.

As all mentioned above it is cleared that we really needed a resilient structure for river flood in phuentsholing and His Majesty's great concern is how our existence structures can withstand the water pressure during monsoon. Our country lies on the great Himalayans in which we received maximum rainfall during summer all across the country, because of this all the flash water reaches in the southern boarder which create huge disaster. The average annual rainfall for Bhutan was 1916.29mm and highest 24hours rainfall in phuentsholing is 285.4mm (NCHM,2017). As far the research done in 2017 maximum flash flood happened in the country are all southern region such as phuentsholing, Pasakha, Gelephu, Samtse and Sarpang and so on. Many interviewers with whom I met so far all are recommended me to mention resilient structures in all southern boarder rivers so that government will give some extra concerns on this place.

CHAPTER FIVE
CONCLUSION AND RECOMENDATION

5.1 CONCLUSION

This paper is based on needs of resilient structures in the Amochu river in phuentsholing are crucial to withstand potential floods, ensuring the safety of communities and infrastructure. This structure must be designed with a comprehensive understanding of the rivers dynamics, considering factors like sedimentation, water flow, and climate impacts. Additionally, community involvement and sustainable practices are essential for the long-term effectiveness of this structures, creating a resilient foundation for the region`s development and safety. As demonstrated in this study, investing in flood-resistant designs, early warning systems, and community engagement can significantly enhance the overall resilience of structures and minimize the devastating consequences of flooding. As we face an era of changing climate patterns, designing in flood resilience becomes not just a necessity but a fundamental aspect of responsible and forward-thinking urban development. Recognizing the unique challenges posed by the river`s dynamics, it is imperative to prioritize sustainable infrastructure development that not only safeguards communities but also promotes resilience. By incorporating adaptive measures and community engagement, we can strive towards creating a robust and resilient environment that withstands the challenges posed by flooding in the region.

As I mentioned above advanced country like Japan is facing huge flood disaster every year even though they had designed such a wonderful model and every year they had to bear huge lost by flood. Bangladesh is a country in which there is disaster management ministry and they even designed PPDM course by thinking that they might give some awareness to the people and other flood risk handling countries. Some of the findings which I found during my research are mention below.

On-going activities in phuentsholing may give resistance to medium flood and short-term protection but if we need to go with strong and long-term resistive structure which can go up to thousand years. The early warning system in phuentsholing is seems to be good after 2023 since both whether forecasting and rising of water level can be inform to people beforehand so that people can be prepared in time. Both automatic and manual early warning system is installing there. Some people said the government is came up with evacuation center in some higher elevation to evacuate people in emergency. As far the seismology of Bhutan, Bhutan lies in seismic zone and zoning phase is divided into four in which phuentsholing lies in zone two which means the research place is highly in danger zone.

5.2 Recommendation- Approach for urban resilience or resilient Phuentsholing.

5.2.1 To suggest them to introduce better flood early warning system.

River flood early warning system is most essential part to inform people regarding rainfall and raising of water level in the river. In order to read this both readings we needed advance early warning system specially in phuentsholing. Latest early warning system is highly encouraged in order to disseminate full-proof communication system to address the loopholes of disseminating disaster warning up to the community level by strengthening of state of emergency. Other factor is that people should understand and utilized the warning system accurately with average knowledge. There will be big gap if only operators know the information.

5.2.2 Modify homes and businesses to help them withstand flood.

Advanced engineering flood resilient building are highly encouraging in the flood prone area so that if river flood occurs in near future there will be huge safe of public and private properties. Without detail refereeing of drawing government should not encourage people to build house and the building build in flood prone area should have different drawing. All the planning work should carry out multi-stake responsibility for example business continuity and supply chain resilience. Business is our future economy of our Country so designing and planning should not be forgotten.

5.2.3 Recommend to construct building above flood level.

All the building which are falling under town planning should have certain height from river bank/resilient structures so that structure will not face any damages if water cross the buffer. River flood is different from others because its flow in high current with boulders, mud and debris from high above which can hit structure continuously when river is swell up. So, government should discourage people to come up with search decision.

5.2.4 Tackle climate change we should implement some adaptation

Tackling climate change and global warming is very important part of preventing flood in the country. If we maintain our forest coverage and emission rate definitely, we can minimize flooding by which we can easily protect our public and private property. As compare to olden days we can feel that temperature is really raise up and seasonal patten had drastically alter and if these changes continue than after fifty years down the line there won't be any season and we have to enjoy only one season. Adaptation of all above mention points are very important in order to control massive flood in future.

5.2.5 Recommend to increase spending on flood risk management.

Finance is the main problem behind the resilient flood structures in the world. A good flood resilient structure can will take over millions of dollars which is not feasible for country like ours. Because of this drawback we are lack behind to come up with good river flood resilient structure in our country specially in Phuentsholing.

5.2.6 Protect wetlands and introduce plant trees strategically.

To protect wetlands is only possible if we plant more trees in and around. To protect and preserve wetlands can also help to provide resistance to flood since it will hold soil leading to erosion. We need to plant trees in such a way that it will give maximum protection against river flood area in phuentsholing. During 18th centuries phuentsholing is covered with dense forest and river can flow on their narrow way but after settlement happened slowly all forest got cut off and flood became active.

5.2.7 Restore River in their natural sources.

Yes, river restoration is an integral part of sustainable water management and is in direct support of the aims of the water framework directives on the national and international policies. Restoring can help in flood management system since it will not be flooded in a new land as well as it is not having to take new path which reduce flooding. As above live watched people told me the river alignment/bank in 1980s is bottom side of mountain opposite side of Phuentsholing town but just not river change its course and reached near to town.

Limitations

Phuentsholing, located in Bhutan, is prone to river flood disasters due to its proximity to major rivers such as the Amochhu and Raidak. While river floods can cause significant damage and pose serious threats to human life and infrastructure, they have certain limitations. Here are some limitations specific to river flood disasters in Phuentsholing:

- **Topography and Drainage Systems:** Phuentsholing topography and drainage systems can affect the severity and extent of river flood disasters. If the region has a well-developed and efficient drainage system, it can help mitigate the impacts of flooding by effectively channeling excess water away. However, if the drainage systems are inadequate or poorly maintained, it can exacerbate flooding and increase the risks.
- **Weather Patterns and Climate Change:** The intensity and frequency of river floods in Phuentsholing can be influenced by weather patterns and climate change. Changes in rainfall patterns, such as increased precipitation or unpredictable weather events, can

lead to sudden and severe flooding. Climate change can contribute to extreme weather conditions, making it difficult to accurately predict and prepare for river flood disasters.

- **Limited Early Warning Systems:** Effective early warning systems are crucial in minimizing the impacts of river flood disasters. These systems rely on timely and accurate information about rising water levels and potential risks. In Phuentsholing, the availability and effectiveness of early warning systems may be limited, making it challenging to provide sufficient advance notice to residents and authorities for evacuation and preparedness.

- **Urbanization and Land-use Planning:** Unplanned urbanization and improper land-use planning can contribute to the vulnerability of Phuentsholing to river flood disasters. Construction in flood-prone areas, encroachment on riverbanks, and inadequate storm-water management can increase the likelihood and severity of flooding. Proper urban planning and zoning regulations are essential to mitigate the risks associated with river floods.
- **Limited Resources and Infrastructure:** Phuentsholing, like many other regions, may face limitations in terms of resources and infrastructure to effectively respond to river flood disasters. Insufficient funds, equipment, and trained personnel for flood management and emergency response can hinder the ability to mitigate and manage flood impacts in a timely and efficient manner.
- **Human Settlements and Awareness:** The presence of informal settlements and lack of awareness among residents can pose challenges during river flood disasters. Informal settlements are often located in vulnerable areas, lacking proper infrastructure and protective measures. Additionally, a lack of awareness regarding flood risks, evacuation procedures, and emergency preparedness can hinder the ability of residents to respond effectively to flood events.
- To do research in Bhutan is very difficult because of limited data sources since there is not many papers published so far.
- Because of poor technology, technical data gathering is almost not possible.
- All manual data collections are not accurate and difficult to include in the papers.
- Diagram from satellite is not clear for some extents.

It is important for local authorities, communities, and relevant stakeholders to address these limitations by implementing measures such as improved drainage systems, enhanced early warning systems, urban planning regulations, community education, and investment in flood

management infrastructure. These efforts can help mitigate the impacts of river flood disasters in Phuentsholing and enhance the resilience of the region.

References

1. Department of Engineering Services, MoWHS, June 2016, Preliminary Flood Hazard Assessment for Dungsumchu in Samdrupjongkhar Dzongkhag, MoWHS, Thimphu, Bhutan.

2. Lhawang Survey & Design Consultancy, 2014, Detailed Engineering and Feasibility study report for Lhamoizingkha & Sarpang flood protection, MoWHS, Thimphu, 70 p.

3. Bhutan Urban Development and Engineering Service, May 2014, Geotechnical Report Sarpang Township, MoWHS, Thimphu, 125 p.

4. Department of Human Settlement, MoWHS, 2010, Sarpang Structure Plan (2010-2035) Final Report Volume 01, DHS, MoWHS, Thimphu, 216 p.

5. Department of Human Settlement, MoWHS, 2010, Sarpang Structure Plan (2010-2035) Final Report Volume 02, DHS, MoWHS, Thimphu, 147 p.

6. Department of Human Settlement, MoWHS, 2010, Shechangthang Local Area Plan (2010-2035) Final Report Volume 01, DHS, MoWHS, Thimphu, 121 p.

7 Anil K. Gupta et al., Disaster & Development (NIDM: 2013) Divya Sharma et al., Urban Climate Resilience: A review of the methodologies adopted under the ACCCRN initiative in Indian Cities (IIED: 2013). Gorakhpur Environmental Action Group (GEAG), Rooting Resilience in Odds (2013). Rana P.B Singh, Urban Planning of the Heritage City of Varanasi (India) and its role in Regional Development. Shiraj A. Wajih et al., Towards a Resilient Gorakhpur (GEAG, ISET & Rockfeller Foundation, 2013). Stephen Tyler et al., Developing Indicators of Urban Climate Resilience (ISET: 2014).

8 Sim, T.; Wang, D.; Han, Z. Assessing the Disaster Resilience of Megacities: The Case of Hong Kong. Sustainability 2018, 10, 1137. [CrossRef]

9 UN. World Urbanization Prospects; United Nations, Department of Economical and Social Affairs: New York, NY, USA, 2018.

10 Hernantes, J.; Maraña, P.; Gimenez, R.; Sarriegi, J.M.; Labaka, L. Towards resilient cities: A maturity model for operationalizing resilience. Cities 2019, 84, 96–103. [CrossRef]

11 Kundzewicz, Z. Climate change impacts on the hydrological cycle. Ecohydrol. Hydrobiol. 2008, 8, 195–203. [CrossRef]

12 Bertilsson, L.; Wiklund, K.; Tebaldi, I.D.M.; Rezende, O.M.; Veról, A.P.; Miguez, M.G. Urban flood resilience—A multi-criteria index to integrate flood resilience into urban planning. J. Hydrol. 2019, 573, 970–982. [CrossRef]

13 Avashia, V.; Garg, A. Implications of land use transitions and climate change on local flooding in urban areas: An assessment of 42 Indian cities. Land Use Policy 2020, 95, 104571. [CrossRef] 15 Behzadi, F.; Wasti, A.; Rahat, S.H.; Tracy, J.N.; Ray, P.A. Analysis of the climate change signal in Mexico City given disagreeing data sources and scattered projections. J. Hydrol. Reg. Stud. 2020, 27, 100662. [CrossRef]

14 Filho, W.L.; Balogun, A.-L.; Olayide, O.E.; Azeiteiro, U.M.; Ayal, D.Y.; Muñoz, P.D.C.; Nagy, G.J.; Bynoe, P.; Oguge, O.; Toamukum, N.Y.; et al. Assessing the impacts of climate change in cities and their adaptive capacity: Towards transformative approaches to climate change adaptation and poverty reduction in urban areas in a set of developing countries. Sci. Total Environ. 2019, 692, 1175–1190. [CrossRef]

15 Kron. W., Dealing with Flood Risk, Stockholm Waterfront, No.3, pp.16, 2006. [2] JICA, Disaster Prevention and Development, http://www.jica.go.jp [3] Wikipedia, Polder, http://ja/wikipedia.org/wiki [4] Bureau of River, Ministry of Construction, On the revised River Laws, http://www/mlit.go.jp/river/gaiyou/houritu/9705.html [5] Wada, K., Graph Shingentei, Yamanashi Nichinichi News, 2003 [6] http://homepage

16 Ashley, Richard, Dennis Parker, Louise Hurley, and Cashman Adrian. 2008. Flooding: Engineering Resilience. Flood Hazard Research Centre. http://redac.eng.usm.my/EAD/EAD511/ Ashley2008.pdf. Asian Development Bank (ADB). 2013. Investing in Resilience: Ensuring a Disaster ResistantFuture.Manila. https://www.adb.org/sites/default/files/publication/30119/investing-resilience.pdf Backhaus, Klaus, Bernd Erichson, Wulff Plinke, and Rolf Weiber. 2016.

23 Multivariate Analysemethoden: Eine Anwendungsorientierte Einführung. Vol. 14. Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-662-46076-4. Barrett, Christopher B, Mark A Constas, Christopher B Barrett, and Mark A Constas. 2014. “Toward a Theory of Resilience for International Development Applications.” Proceedings of the

National Academy of Sciences of the United States of America (PNAS) 111 (40): 14625–30. https://doi.org/10.1073/pnas.1320880111.

17 Kundzewicz, Z.W.; Krysanova, V.; Dankers, R.; Hirabayashi, Y.; Kanae, S.; Hattermann, F.F.; Huang, S.; Milly, P.C.D.; Stoffel, M.; Driessen, P.P.J.; et al. Differences in flood hazard projections in Europe–their causes and consequences for decision making. Hydrol. Sci. J. 2017, 62, 1–14. [CrossRef]

18 Kundzewicz, Z.W.; Kanae, S.; Seneviratne, S.I.; Handmer, J.; Nicholls, N.; Peduzzi, P.; Mechler, R.; Bouwer, L.M.; Arnell, N.; Mach, K.; et al. Flood risk and climate change: Global and regional perspectives [Le risque d'inondation et les perspectives de changement climatique mondial et régional]. Hydrol. Sci. J. 2014, 59, 1–28. [CrossRef]

19Winsemius, H.C.; Aerts, J.C.J.H.; Van Beek, L.P.H.; Bierkens, M.F.P.; Bouwman, A.; Jongman, B.; Kwadijk, J.C.J.; Ligtvoet, W.; Lucas, P.L.; Van Vuuren, D.P.; et al. Global drivers of future river flood risk. Nat. Clim. Chang. 2016, 6, 381–385. [CrossRef]

20 Messeri, A.; Morabito, M.; Messeri, G.; Brandani, G.; Petralli, M.; Natali, F.; Grifoni, D.; Crisci, A.; Gensini, G.; Orlandini, S. Weather-Related Flood and Landslide Damage: A Risk Index for Italian Regions. PLoS ONE 2015, 10, e0144468. [CrossRef] [PubMed]

21Walker, B.; Holling, C.S.; Carpenter, S.R.; Kinzig, A. Resilience, adaptability and transformability in social-ecological systems. Ecol. Soc. 2004, 9, 5. [CrossRef]

22 Dieperink, C.; Hegger, D.L.T.; Bakker, M.H.N.; Kundzewicz, Z.W.; Green, C.; Driessen, P.P.J. Recurrent Governance Challenges in the Implementation and Alignment of Flood Risk Management Strategies: A Review. Water Resour. Manag. 2016, 30, 4467–4481. [CrossRef]

Yuto Shiozaki and Takaaki Kato, "Definitions of Resilience and Vulnerability in Natural Disaster Research and Related Fields," Seisan Kenkyu 64, no. 4 (2012): 643-646, https://doi.org/10.11188/seisankenkyu.64.643. – in Japanese.

Appendix 1

A. General information

Name ……age…… gender……. household no……. cid……. village/town……...geog……Dzongkhag……. date…….

- From when you are staying here?
- Is this town your birth place? If not where is your birth place?
- What is your family status?
- What is your main source of income?
- Are you doing business? If yes what type?
- If your work satisfied you for living?
- What is your monthly income?
- What type of shop you own?
- From when you are doing this business?
- Your maximum sell items?
- Your shop is whole sale?
- Are you happy to do your business although it is ganger of flood?
- What are the pro and con of living in the flood risk area?
- Are you doing a job?
- What type of job you are doing?
- It is private or government?
- Is your salary enough for your living?
- Are you satisfied to your work?
- Do you think this place is safe for river flood?
- How can we improve the river flood resilient structure?
- Do you have any idea to improve this?
- Are you happy with early warning system?
- Do you we need changes on early warning system?
- Do you think government is really working hard on river flood risk reduction field?
- If no in what way government is failing?
- Do you think what is our failure to come up with good river flood resilient structure?
- What is your suggestion on needs of river flood resilient structure in phuentsholing?

B. social mapping

Name of the town…….

Number of attended…….

Number of people interviewed…….

How old this town?

Main occupation of people?
Main income of the people?
Natural resources found in this town?
Total no. of school available in the town?
Total no. of BHU in the town?
Total no. hospital in the town?
How many cultures are there in the town?
How many temples are there in the town?
Drinking water facilities in the town?
How about the sanitation and cleanness?
Total no. of shops in the town?
What about the transportation facilities?
What is the road condition?
What about the city bus services?
Town is having disaster management or not center?
What about the government office allocation? Yes or no
If yes what is its purpose?
What about disaster early warning system?
What about the river disaster in the town?
What is action taken to minimize river disaster risk in the town?
How many bridges are available in the town?
What about the evacuation center in the town in times of disaster?
Do our early warning system really working effectively?
Do we need advance GPS and GIS system?
If your town need river flood resilient structure what type you will recommend?
What are our main limitations?
Are we financially bold?

C. issue of vulnerability

Name of the town……..

Number of interviewed people……

Si no.	**Issue**	**zone**	**statistics**

1	Buildings		
2	Shops		
3	Schools		
4	Hospitals		
5	BHU		
6	Play field		
7	Water sanitation centers		
8	Lack of land		
9	Domestic animals		
10	Canals		
11	Without electricity		
12	Food shortage		
13	River bank erosion		
14	Drainage system		
15	Corrupted officials		
16	Corrupted offices		
17	River training structures		
18	culvert		
19	bridges		
20	monastery		
21	No of early warning system		
22	Total no. of people in the town		
23	Decline of a income		
24	Transportation way types		
25	vehicles		
26	business		
27	Food		
28	Way of living		

D. History of river flood disaster in phuentsholing

Name……CID……..Gender…….age……..geog…….dzongkhag…….village…….date

What is river flood disaster?

When did Toorsa flood occurred?

In which year did biggest flood occurred?

When did flood use to occurred?

Have you experience river flood disaster?

If yes how many times?

If no do you have any idea about flood?

How you notice the cause of river flood?

Do you have any idea of source of Toorsa river?

Are you being in the source of Toorsa chu?

If you have little knowledge can you explain about 2016 river flood in phuentsholing?

Do Toorsa have early warning system in 2016?

What is your feeling if you again face such disaster?

What is the effect of flood in phuentsholing?