COMMUNITY-BASED MANAGEMENT OF GLACIAL LAKE OUTBURST FLOOD: A CASE STUDY OF SAMDINGKHA VILLAGE IN BHUTAN

A Dissertation for the Degree of Master in Disaster Management

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Abstract

Climate change is contributing to increased melting of glaciers and formation of glacial lakes. The threat of Glacial Lake Outburst Floods (GLOF) is posing a serious threat to the lives and livelihoods of the Bhutanese people. The melting of glaciers is leading to alarming volumes of water in downstream glacial lakes. Increased temperature also causes melting of ice-cored moraine dams to the point that the ridges can no longer resist the pressure. The concern is that when the current holding capacity of the lakes reaches a critical threshold, loose glacial debris that act as dams or barriers could fail and lead to flash floods. This phenomenon results in severe adverse impacts on downstream communities.

A large number of communities in the Punakha Valley are vulnerable to GLOF from Glacier Lake at sources of Pho Chu. The risk of damage to their agricultural fields, washing away critical infrastructures, killing of cattle and even losing lives has increase in recent years. Further increased glacial melting and GLOF will have devastating effects on the hydropower plants in the country. 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 Pho Chu in Samdingkha Village. Field data were collected from Samdingkha village as part of the case study. The information was collected through participatory tools and further followed by DIFDs livelihood analysis guidelines and Expand – Contract Model. To assess the information, literature were reviewed from different journals, books, government policies, meteorological and hydrological data and other unpublished thesis work and articles.

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Abbreviation

ADPC	Asian Disaster Preparedness Center
BHU	Basic Health Unit
CBDR	Community Based Disaster management
DDM	Department of Disaster management
DFID	Department for International Development
EWS	Early Warning System
FGD	Focus Group Discussion
GEF	Global Environment Facility
GLOF	Glacier lake Outburst Flood
HFA	Hyogo Framework for Action
ICIMOD	International Center for Integrated Mountain Development
IPCC	Inter-Governmental Panel on Climate Change
JAXA	Japan Aerospace Exploration Agency
NAPA	National Adaption Programme of Action
NEC	National Environment Commission
NGO	Non Government Organization
NSSC	National Soil Service center
SL	Sustainability Livelihood
SLF	Sustainability Livelihood Framework
ToR	Terms of Reference
UNDP	United Nations Development Programme
UNISDR	United Nations International Strategy for Disaster Reduction
WWF	World Wildlife Fund

Glossary of Bhutanese terms

Dzong	A monastery – fortress, which usually functions as the district, headquarters for public administration as well as for monastic affairs.
Dzongkhag	District
Gewog	Smallest Geographic unit public administration made up of a block.
Chu	River
Tsho	Lake

CHAPTER 1
INTRODUCTION

1.1 Background of research

Bhutan is land locked and mountainous country 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. About 72% of the country is forest. The constitution of Bhutan demands that 60% land shall be maintained as forest at all time. The Bhutan Himalaya Mountain is spread over 340 km and dominates the northern part of the country. The Tibetan Plateau of China borders Bhutan to the north, India is located in south, east and west. Bhutan 's population is about 700,000 people (683,407 in 2009 based on PHCB 2005 projections). Bhutan has three distinct climate zones namely, 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 one of world's important carbon sink. It absorbs more CO2 than it gives out. However Bhutan experiences adverse effect from climate change. Global warming has led to negative glacier mass balance, causing glacier retreat around the Bhutan. Glacier in Bhutan covers about 10 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 677 glaciers covering an area of 1317sq.km, and 2674 glacier lakes with 107sq m and 25-glacier lake potential thereat. According to Japan Aerospace Exploration Agency (JAXA) a new glacial inventory in Bhutan reveals 2 Glacier lakes as potential dangerous instead of 25 as reported earlier by the ICIMOD, 2001.

According to NEC outlook 2008, the Himalayan glaciers in Bhutan are retreating at a rate of 20m-30m a year. As a result there is rapid accumulation of water in the form of lake in front of the glacier. The inherent instability of moraine or ice dam can be triggered easily by other hazard, like Avalanches, Landslide, Rock fall and Earthquake. The immediate discharge of huge volume of water and debris pose threat to lives and livelihood asset in the downstream valley. Some glaciers that are in disequilibrium with present climate change have already disappeared. Increase temperature is expected to cause glacier to melt, which will result in formation of numerous glacier lakes and increase in the rise of Glacier Lake's level. Excessive rise of glacier lake level or fall of huge ice or debris in glacier lake may led to sudden discharge in collapse of the dam and result in release of water and mud. This phenomenon of flooding is called " Glacier Lake Outburst Flood" (GLOF).

GLOFs are among the most serious natural hazards potential in the country. GLOF have taken place in Bhutan in the past in 1957,1960 and the most recent one in 7th October 1994 from Luggue Tsho Glacier Lake erupted down the Pho Chu and Punatshang Chu River claiming 22 lives, 1700 acres of agriculture land and huge loss of property, environment and ecosystem (DMG Bhutan).

Glacier and Glacier lakes are 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 fact that Bhutan's economy is highly dependent on hydropower resources, it is term as "WHITE GOLD"(water). They are Bhutan greatest asset, which needs to be protected. Increased melting would cause great flow for several decades, after which " some areas of the most populated region on Earth are likely to run out of water" (Barnett *et al,* 2005). But in other hand GLOF can be very devastating to lives and property of many people. It is alarming to note the risk from adverse impact of climate change in giving birth to GLOF. As huge portion of Bhutanese population are settled in very fertile valley along the river system. Not only livelihoods of Bhutanese people are at risk but also be the cause of huge damages to important infrastructure such as hydroelectric dams.

All most all the settlements in Bhutan are along the river valley, and prone to multiple natural hazards. "The local community is taken as the primary focus of attention since that is the common unit which is affected by disaster and, more importantly, responds to deal with event."(Russell Dynes) " Whether a disaster is major or minor, of national or local proportion, it is the people at community or village level who suffer its adverse effects. They use coping and survival strategies to fact and respond to the situation long before outside help from NGOs or the government arrives.

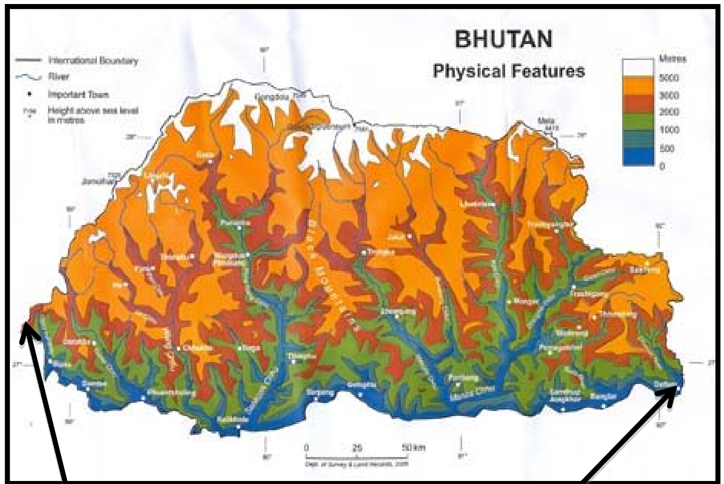

Figure 1.1: Physical Map of Bhutan. Source: mapsofworld.com accessed on 17th Oct. 2012

Figure 1.2: Physical Map of South Asia. Source: mapsofworld.com accessed on 27th Oct. 2012.

They are interested to protect themselves from the damage and harm. (Victoria, Center of Disaster Preparedness)

Climate Change threats of GLOF are increasing, this threat was taken up to developed better understanding on management of GLOF at community level. A better understanding would improve disaster management.

1.2. Problem and Justification of Research

In this research study, Community Based GLOF Disaster Management has become very important and to understand the dynamic of glacial flooding, which can reduce and strengthen by community approaches.

GLOF characteristic is similar with flash flood, but incase with GLOF, the increasing temperature due to global warming is accelerating the retreat of glaciers, causing glacier lakes formation, which directly increases the frequency and magnitude of moraine dam failures. The failure of a moraine dam and ice dam is hazardous as the resulting outburst flow is rapid with high discharges with very high peak flood. GLOF impact at downstream where community livelihood are being destroyed, which can reduce its vulnerability and risk by CBDM.

The past two GLOF 1957 and 1960 did not have any record, but 1994 GLOF with history and the latest hit area should be benchmark for further study in relation to GLOF. And also in my research study 7th Oct. 1994 GLOF is main backbone.

1.3 Research Objectives

The objective of the research study will be to understand basic GLOF Disaster Management through Community Based Approaches.

1.3.1 **The specific aims and objective are**: -

- To access of local knowledge on Community Based Disaster Management.
- To study the impact of GLOFs on livelihood of people in affected area.
- To evaluate the present level preparedness for Community Based and Disaster Management.
- To recommend steps to make the people aware and better prepared for GLOFs.

1.4 Research Questions

- The Implication of GLOF events affecting the people living in downstream valleys?
- How can community be better equipped to face the GLOF events?
- How do the community perceive the GLOF risk?
- Why does community lives in the vulnerable area?
- How are they prepared in case of GLOF events happen?
- What assistance they get from government and development agencies to reduce the risk?

1.5 Thesis Outline

This thesis is divided into five chapters. The first chapter being the introduction gives an overview of global climate change, the increasing temperature, and its impact on glacial lakes. It also touches on presence of glacial lakes in Bhutan and the past GLOF events and Impact on Hydropower. The Implication of GLOF events, which cause the loss of livelihoods downstream communities, are being address in research objective and questions. Chapter two presents literature review with background information on hazards and risk of GLOF. Chapter Three describes what methods and instruments of data collection I use to study the communities and the study area. Chapter Four presented result by discussion. Significant of the study is highlighted while exploring some implications in Chapter Five.

CHAPTER 2
LITERTURE REVIEW

2.1 Terminology used in the research

2.1.1 Climate Change

Climate change refers to a statistically significant variation in either the mean stats of the climate or in its variability, persisting for an extended period. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC 2001). Climate change is a human induced process related to Greenhouse gas emission.

2.1.2 Global Warming

The Global Warming means the increase in the average temperature of the earth surface and the ocean in the past, present and projecting the future. The main causes of the global warming are human causes, such as greenhouse effect and natural causes and solar variation.

2.1.3 Climate Variability

Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (IPPC, 2004)

2.1.4 Hazard

“A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can include conditions that may represent future threats and can have different origin: natural (geological, hydro meteorological and biological) or induced by human processes (environmental degradation and technological hazards). Hazards can be single, sequential or combined in their origin and effects. 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)

2.1.6 Vulnerability Assessment

Vulnerability assessment "measures" the physical, social, economic and environmental factors or processes, which increase the susceptibility of the community 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

"The probability of harmful consequences, or expected loss of lives, people injured, property, livelihoods, economic activity disrupted (or environment damaged) resulting from interactions between natural or human induced hazards and vulnerable conditions. Risk is conventionally expressed by equation: Risk = Hazards X Vulnerability" (UNDP, 2004).

2.1.8 Disaster

A disaster is an event, natural or man made, sudden or progressive, that seriously disrupts the functioning of a society, causing human, material or environment losses of such severity that the affected community has to respond by taking exceptional measures (ADPC).

2.2 GLOF in Bhutan

2.2.1 Glacier

Glacier is huge mass of ice body that is formed over the period of years when it exceeds ablation. Over the period of times as the time pass slowly the snow and ice get accumulate and become very thick. Due to the weight upon each other and gradient of slop, at certain state they begin to move. There are two type of glacier Clean (C-type) and Debris (D-type). In Bhutan Glacier ice is the largest reservoir of freshwater and which make most of Major River perennial. On the account of climate change properties, e.g. precipitation, mean temperature, and glacial mass change can affect the life of glacier is been threaten in term of shape and size even its existence. And rapid melting of Glacier Lake threatened the glacier lake outburst flood. **“**Among the basins and sub-basins of the Bhutan Himalayas, Amo Chu and Nyere Ama Chu Basins as well as Ha Chu and Dang Chu Sub-basins have no glaciers. The Pho Chu Sub-basin has the highest number of glaciers and the Thim Chu Sub-basin the lowest. The northern basin, where the drainage originates in Bhutan and flows towards Tibet (China), has only 59 glaciers but the area occupied by the glaciers in this basin is largest. Altogether there are 677 glaciers with an area of around 1,317 sq.km. The estimated ice reserve is 127 km3” (ICIMOD, UNFE 2001).

2.2.2 Glacier Lake

Glacier Lake is formed due to melting of glacier, which has been activated by the rise in temperature. Glacier lake are formed in depression area of glaciers surrounded by the lateral and end moraines dam or may formed at the side of lateral moraine extended glacier due to interception of the tributaries by its lateral moraine. “There are total of 2674 glacial lake covering area about 107 sq.km” (ICIMOD, 2001)

Glacier lakes were classified into three types based on location, mode of formation and recent condition:

(a) Supra glacial ice-melt ponds or lakes: most are small and shallow in size, but they tend to connect to each other and grow into large contiguous lakes.

(b) Moraine-dammed lakes: some lakes store large quantities of water and have probability of GLOFs that could cause severe damage downstream.

(c) Lakes location in basins far from glaciers or without glaciers: they are located in cirques or glacial troughs, which were by Pleistocene glaciers. These lakes are stable because of solid rock spillways and no direct influence of glacier variation.

2.2.3 Potentially Dangerous Glacial Lakes

In 2001, a study by ICIMOD and UNEF identified 2674 glacial lake of which 25 are identified as potentially dangerous glacial lakes in Bhutan shown in figure 2.1.

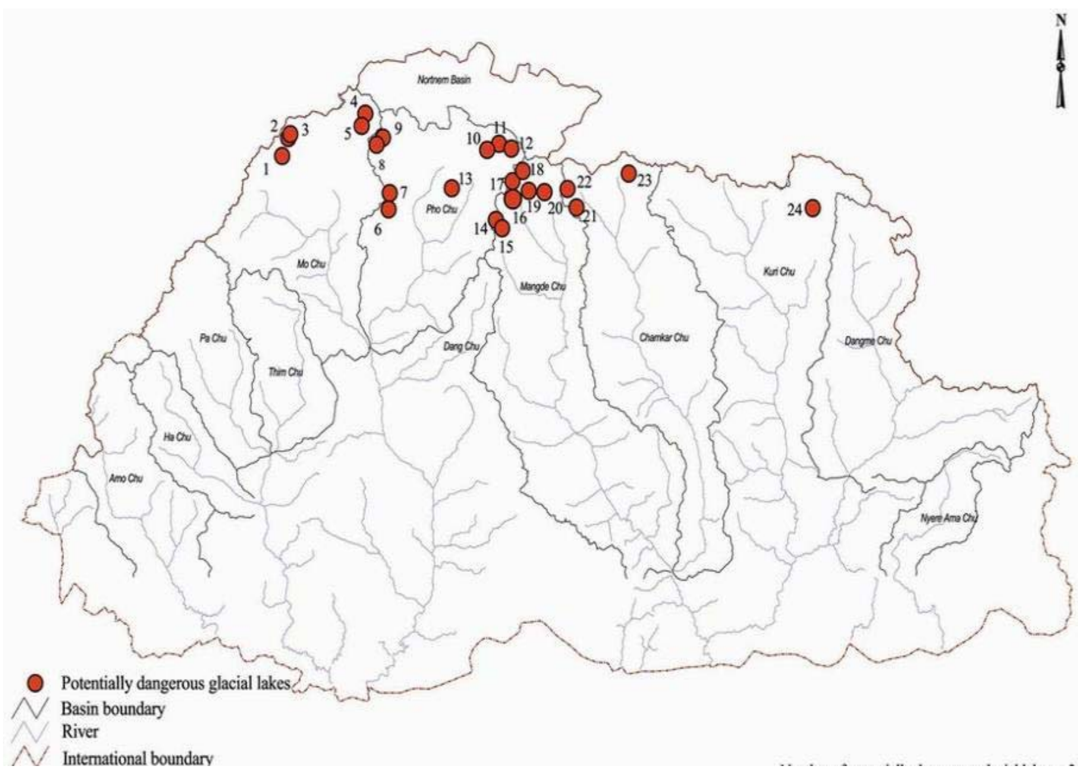

Figure 2.1: Potentially dangerous glacial lakes (dots) in Bhutan, Source: ICIMOD/UNEF, 2001

2.2.3 On-Going Action Taken on GLOF

Royal Government of Bhutan is aware of the current situation of the melting of glaciers is increasingly huge volumes of water in downstream glacial lakes. Thereby posing a serious threat to the lives and livelihood of the Bhutanese people. Moraine dams are not able to withstand the pressure any longer due to increased temperature. And also concern about the current holding capacity of water in the lakes reaches a very critical stage, where by moraine dams or barriers burst and lead to glacier lake outburst flood that could result in severe adverse impact on downstream communities.

The Bhutanese government had taken step in reducing the threat of glacier lake flooding from rising water levels. In coordination with UNDP Bhutan developed the project with a total budget outlay of US $ 7,481,274 with fund from Global Environment Facility (GEF), UNDP, the Austrian Government and World Wildlife Fund (WWF) entitled "Reducing Climate Change-Induced Risk and Vulnerabilities from Glacier lake outburst flood in Punakha - Wangdi Phodrang and Chamkhar valleys" with the objective to reduce Climate Change – Induced Risk of Glacier lake Outburst Flood (GLOFs) in Punakaha – Wangdi Phodrang and Chamkhar Valleys.

The project's first outcome, which improves national, regional, and local capacities to prevent Climate Change – Induced GLOF disasters, will address the needs to incorporate climate change into ongoing disaster risk management decision-making and practices.

Artificial measures taken in lowering the water levels that can change dam structures may trigger catastrophic discharge events. For example, in Peru in 1953, during the artificial lowering of the water level, an earth slide caused 12m high displacement waves, which poured into a trench, excavated as part of the engineering works and almost led to the total failure of the moraine dam. The Bhutanese government has taken great risk and move forwarded and adopted the project's second outcome will reduce the risk of Climate – Change induced GLOF by artificially lowering the water level in Thorthormi Lake. As of now this ongoing project is going to end by 2012.

Figure 2.2: Workers in lowering of glacial lakes, Source: DMG/DGM, 2010

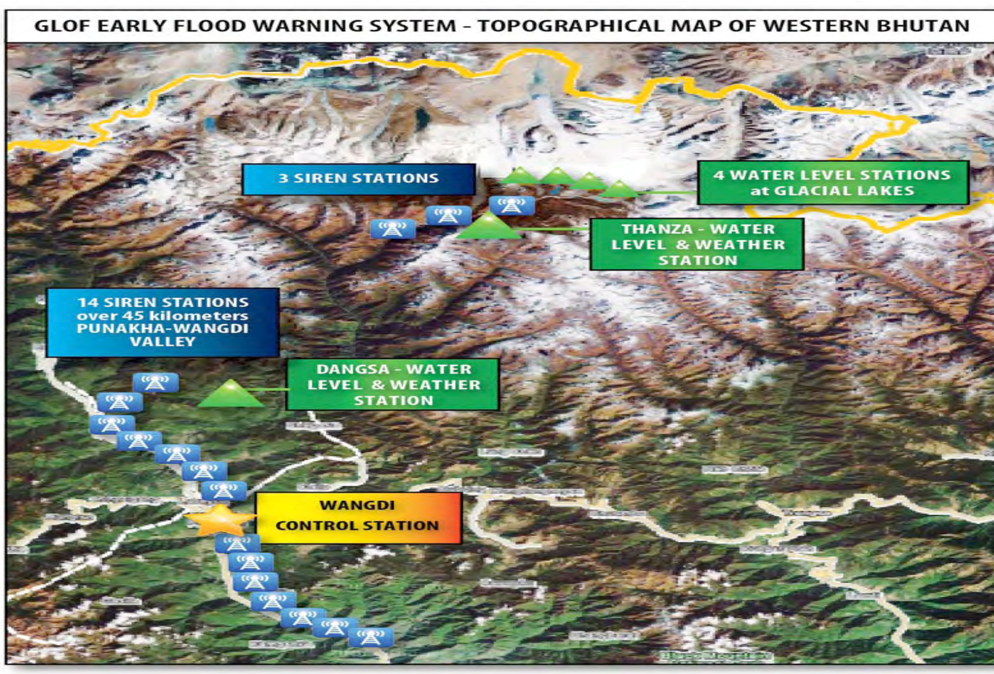

Figure 2.3: Installation of early warning system in Bhutan, Source: Hydro Met of Bhutan, 2009

The project's third outcome, reduce human and material losses in vulnerable communities through GLOF Early Warning will enhance the resilience of vulnerable communities in Punakha – Wangdi Phodrang valley. Sutron Corporation have install Iridium satellite and made operational in mid 2011.

The project's fourth outcome, enhanced learning, evaluation and adaptive management focuses on enhance the learning and knowledge exchange, enabling the replication of effective disaster risk reduction measures and adaptation to climate change both within Bhutan and with other countries facing climate change – induced GLOF risks.

2.2.4 Glacier lake outburst Flood

In recent years Bhutan history has experience three glacier lake outburst floods (GLOF) i.e. in1957, 1960 and 1994. All the three GLOF had taken place in Pho Chu sub-basin. The 1994 GLOF, which was caused by partial burst of Lugge Tsho in eastern Lunana, it cost lives and damage more than 1,700 acres of agricultural and pasture land.

Similarly like pho Chu sub-basin there are in others region that fall within the chamkhar Chu basin, the Mangde Chu basin, Mo Chu basin. Over all, GLOFs constantly threaten the lives and livelihood of people living in the valley and low lying river plains. Which is susceptible to damage the industrial infrastructures such as hydropower projects and low lying bridges and all the infrastructures along the river.

2.2.5 Glacier Lake Outburst Flood and causes

Glacier Lake bursting has different mechanisms, which mainly depend upon the stability, and material dam are composed of, the position and direction of lake located, content of water volume, physical and topographical condition, and also surrounding condition. Main trigger events, which lead to an outburst flood:

- Surge wave which lead to dam burst caused by

- Ice avalanches
- Large ice and rock fall or debris flows into the lake
- The earthquakes can one of major trigger event for bursting of lake, where movement of tectonic plates can dis-balance the moraine. Not only that shaking of lake water and over flowing of water over the moraine will causes regressive erosion and eventual lake outburst.
- Rising water level in lake, which is caused by seasonal rise in temperature that increases the melting rate of ice by increasing volume of water in lake. And ultimately increase the pressure in moraine.
- The landslide can be one of cause with the two adjacent lake, when one dam break and flow over to another and forming one huge volume of water lake that can result in bursting of lake.
- Human activities with the idea of artificial lowering of water level of lake with different engineering skill can change dam structure may trigger natural flow and lead to bursting.

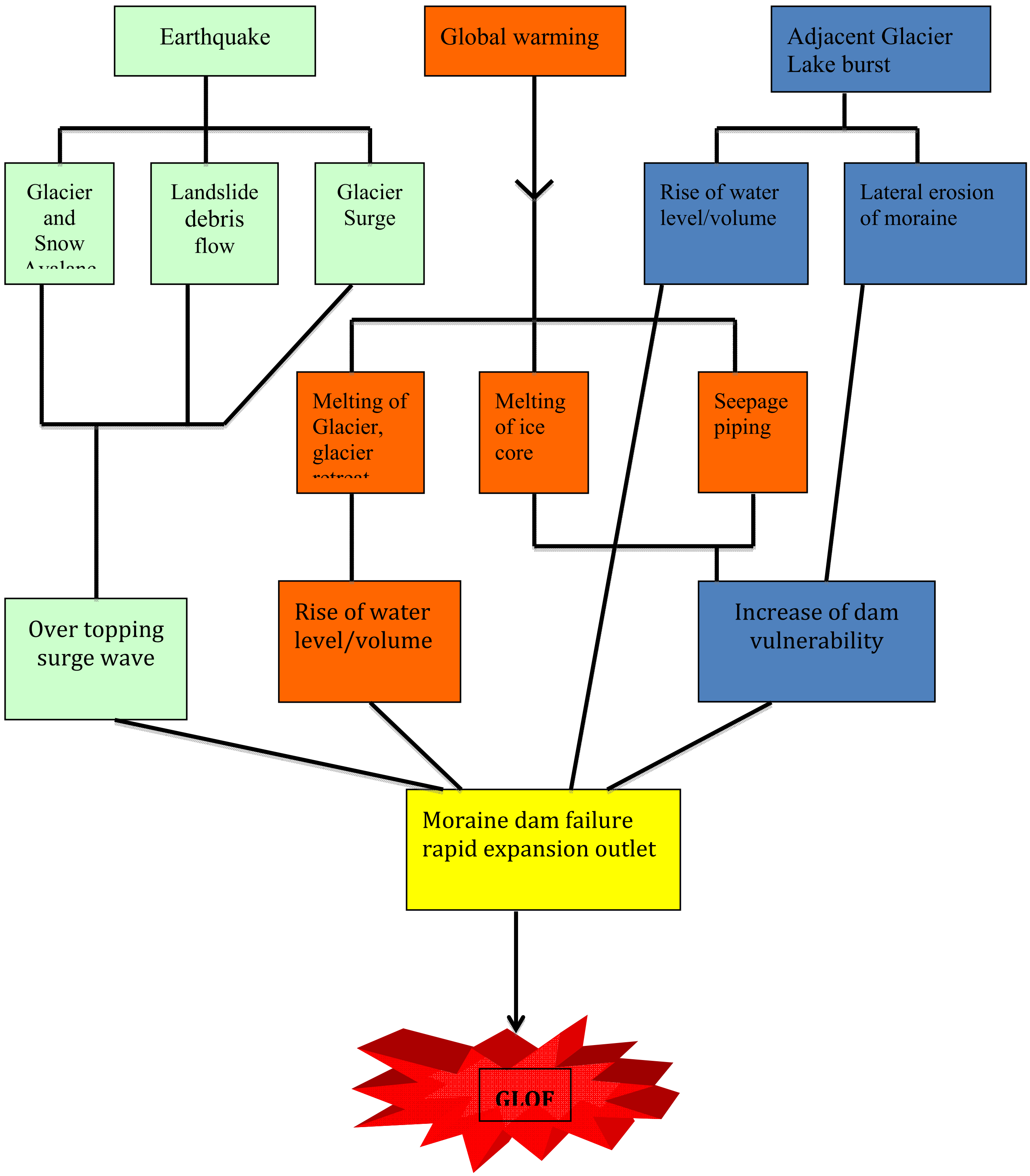

Figure 2.4: Flow chart showing possible trigger and causes of GLOF

2.2.6 Early Warning System

2.2.6.1 Manual Early Warning System

Manual early warning with help of limited resources and local resources it make very effective in times of disaster event. In Punakha Dzongkha there are 8 mobile phones were provided to early warning focal points along the vulnerable area (from Wolathang to Tshokna) and they were also provided with a flex load of Nu.50 on a monthly basis for first year. In 2010 flex load increased to Nu.150 per month said by the Dzongkha focal person. Further mention that the use of mobiles proved to be very effectively to communicate any early warning from the Dzongkhag to the communities and the Dzongkhag also used the focal point to gather any disaster related information.

The community felt that the manual early warning system was effective and should function even with the institution of the automatic early warning system.

In case of GLOF almost half of the total respondents in Punakha and Wangdue, felt GLOF events could occur during periods of heavy rainfall and a significant number believed it could happen immediately after an earthquake or due to the rapid melting of snow (21.8 and 12% respectively). About 11% of the respondents could not relate any reason and a small number (2.4%) still had the traditional belief of GLOF events occurring due to the "wrath of the deities protecting the lakes".

2.2.6.2 Automatic Early Warning System

The Royal Government with UNDP, GEF and WWF have launch project in installation of early warning system along the downstream in GLOF affected area. The project has installed 17siren tower and 6 hydro-met monitoring stations. The system is dived into two geographical areas: the upper sites near the glacial lakes, the source of the GLOF, and the lower sites of the Punakha-Wangdue valley where majority of the population is located. In addition 4 water level sensors have been installed in the glacial lakes at Lunana, 5 sensors at Thanza and 1 sensor at Dangsa, Tangme Damchu. In addition, 1 automatic water level sensor each has been installed at Lunana and Dangsa. Each sensor was tested during installation and the Department of Energy, the agency responsible for installation of the automatic early warning system is confident that all vulnerable areas in Punakha/Wangdue valleys are adequately covered.

2.3 Hazard Zonation Concept

In order to identify hazard-prone areas in downstream valley where lives, sustainable livelihood and more over huge investment in Hydro project will be threaten in the event of GLOF. Therefore there is must for Hazard zone demarcation in prone area in the area where precious infrastructure and community assets. Not only that hazard zonation will help in contributing useful inputs to disaster risk management practitioners and administration in earmarking hazard prone and vulnerable area. The Austria-Bhutan (1998-2002) and DMG-NCAP project had done with the hazard zone demarcation, which was carried out based on the result and hazard zonation concept and map prepared by the project only. Hazard zonation areas in downstream were categorized under three different hazard zone based on the degree of risk exposed to GLOF and represented with three color coding (RED, YELLOW and BLUE). The following are color coding indication.

RED ZONE: This represents high risk areas where most probably water level will reach and the areas will be submerged in case of the worst case scenario. Therefore this zone is a restricted zone where incase of worst case GLOF in future the structures will be submerged under water.

YELLOW ZONE: This represents medium risk areas where most probable indirect impact of GLOF can occur during the worst-case scenario. Therefore future developmental activities should be planned accordingly.

2.3.1 Hazard Zonation Concept Table

ZONE	Individual Risk	Common Risk
RED "Prohibition Zone"	**Generally**: Individual area endangered inside and outside of buildings. Heavy processes having a high recurrence probability.	**Generally**: Buildings are completely destroyed. **Only water floods**: When buildings are completely flooded up to the roof or people cannot escape onto the roof.
YELLOW " Regulation Zone"	**Generally**: Individuals are endangered only outside of buildings. Heavy processes having low to medium recurrence probability. Gradual processes having medium to high recurrence probability.	**Generally**: Buildings can be partly damaged.
BLUE "Regulation Zone"	**Generally**: People are only slightly endangered outside buildings. Processes, which do not have high or medium recurrence probability.	**Generally**: Damages to buildings are not probable. Processes don't have high recurrence probability.

Table 2.1: Hazards Zonation Concept © DGM and DDM

2.3.2 Identification of Safe Evacuation Area

Identification of Safe Evacuation area is very essential in times of disaster in order to reduce to loss. It will be very easy to work out the safe zone if hazards zone map are formed. Therefore Department of disaster management and department of Geology and Mines had identified evacuation area for the Samdingkha village. And they have adopted the following criteria while identification safe evacuation area.

- The evacuation area should be for a group of settlements as far as possible to avoid confusion incase of GLOF disaster.

- The identified area be connected with at least fairly good road/foot track with the settlement/community

- The identified area be well within the shortest possible distance from the settlement/community

- The identified area be in an open and unused land for other activities such as agriculture

- The identified area be at a safe location during GLOF.

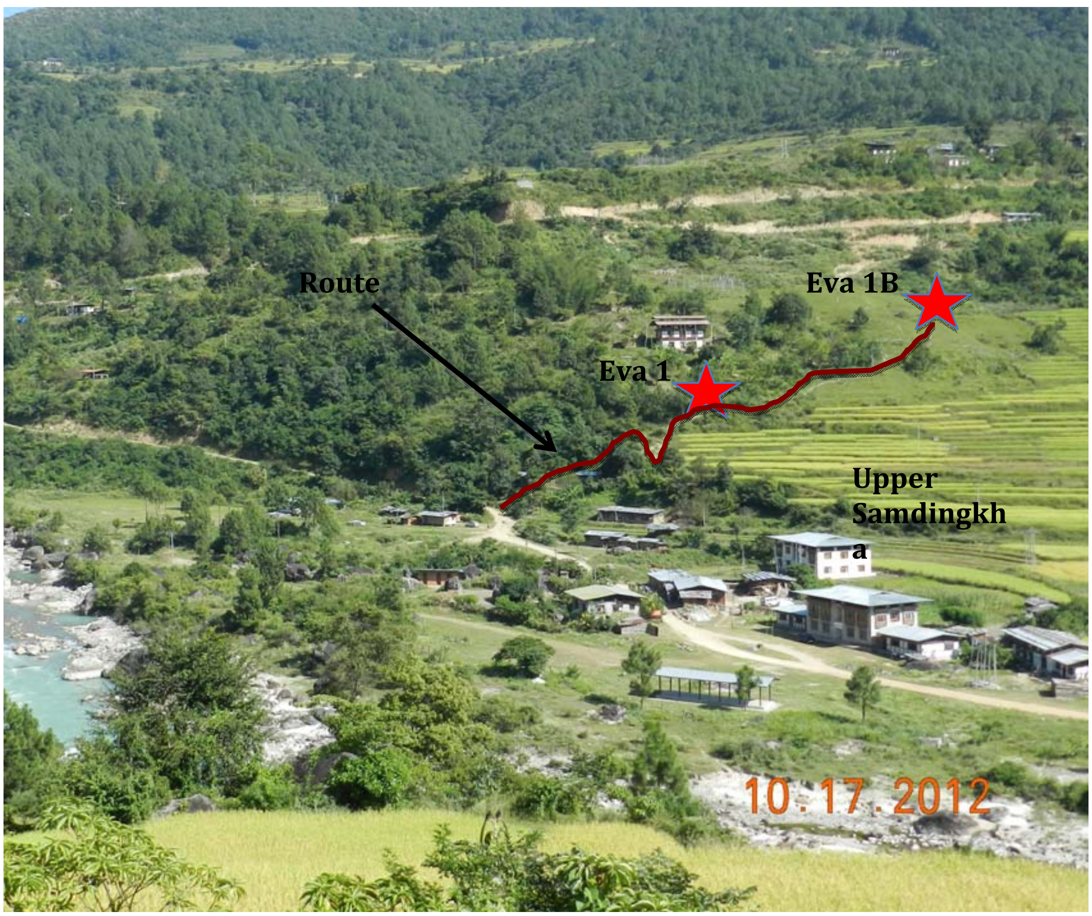

Figure 2.5: Evacuation site and route for upper Samdingkha as on 17th Oct. 2012 (Photo by author)

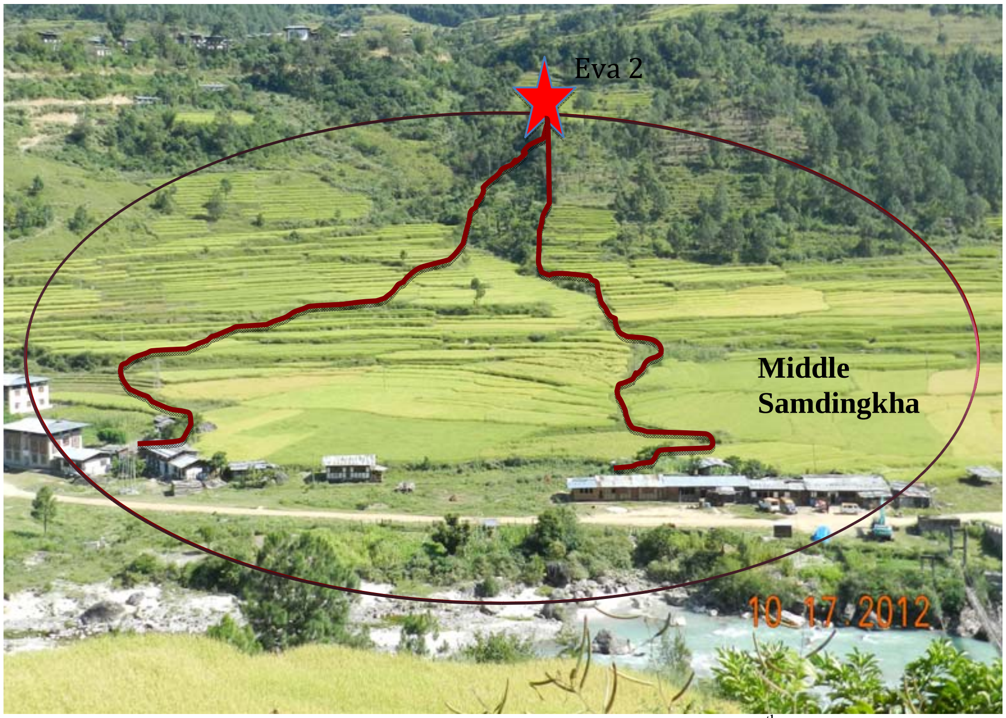

Figure 2.6:Evacuation site and route for middle Samdingkha as on 17th Oct. 2012(Photo by author)

Figure 2.7: Evacuation site for lower Samdingkha as on 17th Oct. 2012 (Photo by author)

The Upper Samdingkha consists of the houses shown in the figure 2.5, which includes 2 permanent houses, and rests are all semi-permanent and temporary sheds. For entire area of upper Samdingkha, 2 areas were identified as safe evacuation area (Eva 1 and Eva 1B). The details for the evacuation plan are provided in table

For the middle Samdingkha consist of the house shown in figure 2.6 and for this settlement there is one evacuation area (Eva 2). Which is in middle upper level of paddy fields and the area is in open area with trees around it. There are two routes towards the evacuation area along both along the irrigation channel.

In lower Samdingkha there are two permanent houses located in the red zone area and the evacuation site is in the Samdingkha Basic Health Unit (BHU) ground as shown in the figure 2.7.

2.3.3 House falling under Red zone and details of evacuation plan

Locality Name/Village & No of grouped houses	**Distance to the proposed evacuation site (m)**	**Direction to move to avoid GLOF**	**Time estimated on normal walk**	**Evacuation area NO and elevation**	**Remarks**
Samdingkha (Upper) 3 permanent houses and 5 semi-permanent houses fall in Red Zone	200m to 300m	Due south	1min or 2 min	Eva 1 1295m and Eva 1B 1310m	Up-slope existing foot track to the higher level of houses. Eva 1B also kept at higher level for optional
Middle Samdingkha 2 permanent houses and 5 semi-permanent house (Red zone)	300m for 1st 2 permanent houses and 400m for 5 semi-permanent houses.	S30 degE to S40 deg.E	3min for 2 houses and 4 min for 5 houses	Eva 2 1288m and lies in the middle of paddy field	should follow the existing irrigation channel

Table 2.2: Sources Hazard demarcation, Department of disaster management of Bhutan

2.4 Community Based Approaches To Disaster Management

Community participation has been recognized as the additional element in disaster management necessary to reverse the worldwide trend of exponential increase in disaster occurrence of and loss from small and medium scale disasters, build a culture of safety, and ensure sustainable development for all. The process of disaster risk management in which at-risk communities are actively engaged in the identification, analysis, treatment, monitoring and evaluation of disaster risk in order to reduce their vulnerabilities and enhance their capacities. This means people at the heart of decision-making and implementation of disaster risk reduction activities.

Whether a disaster is major or minor, of national or local proportion, it is the people at community or village level who suffer its adverse effects. They use coping and survival strategies to face and respond to the situation long before outside help from NGOs or the government arrives. They are interested to protect themselves from the damage and harm.

2.4.1 Disaster Management?

When there are causes for losses of lives and/or properties then natural event becomes a disaster. Since disasters affect people's livelihood, involvement of people as individuals, and community as collectives, are important to reduce the impact of disasters.

Disaster management is directly linked to human security. Many of the natural disasters, like floods and drought, found to be directly related to environmental degradation and climate change. These disasters hurt the poor people the most by affecting their lives, properties and livelihoods. Therefore, by creating disaster resilient communities, it is possible to improve human security.

During the United Nations International Decade for Natural Disaster Reduction (UN IDNR, 1990-1999), a paradigm shit has relief and rescue to pre-disaster mitigation efforts. Another focus area was empowerment of local governments and involvement of non-governments organization and civil societies in the decision-making system.

2.4.2 What is Community?

The word "community" is derived from the old French communité which is derived from the Latin communitas (cum, "with/together" plus minus, "gift"), a broad term for fellowship or organized society.

"Community is defined as a feeling that members have of belonging, a feeling that members matter to one another and to the group, and a shared faith that members' needs will be met through their commitment to be together" **(**McMillan and Chavis, 1986, Sense of Community: A definition and theory, Journal of Community Psychology, 14, 6-23).

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 (CBDM).

2.4.3 Importance of Community involvement

The key aspect of community involvement is the sustainability of common level initiatives for disaster reduction. External agencies like government, NGOs may initiate and implement community level programs before and after disasters.
However such initiatives many times discontinue once the external support ends.

Community involvement is therefore paramount as local communities know their own opportunities and constrains resulting in better identification of risk, vulnerabilities and required mitigation efforts. Also, unless the disaster risk management efforts are sustainable at individual and community level it would be difficult to reduce their vulnerability and losses. Local communities have an active part to play before and after disaster as:

- A good state of disaster preparedness may reduce its impacts

- More number of lives can be saved during the first few hours after disaster and has occurred through local response team, before help arrive from elsewhere

- The numerous problems of survival and health resulting from a disaster are dealt with more efficiently, if the communities are active and well organized (WHO, 1998)

2.4.4 Community Based Disaster Management Approach

Although indigenous coping mechanisms have existed for as long as human history, the term Community Based Disaster Management (CBDM) was first used more popularly in the middle of 1990s in the Asian region following the realization that:

- The local population in a disaster prone area, due to exposure and proximity, are the victims and assume most of the responsibilities in coping with effect of disasters

- The local population has local knowledge of vulnerabilities and repositories of any traditional coping mechanisms suited for the own environment

- The local population responds first at times of cries and the last remaining participants as stricken communities strive to rebuild after a disaster

"CBDM achievements are "small wins" that vulnerable communities contribute to grander goals of disaster reduction." (IDRM)

CBDM has been a popular term for the last several years. In a few case it was incorporate into government policy. It has been a common notion that CBDM is the responsible of the grass root organizations and NGOs. There are two major aspects in this regard:

- First, the best practices of CBDM initiatives become local initiatives, without proper dissemination. For example even though there have been good examples of CBDM in a certain location in a country, the lessons are not transferred to other parts of the country, nor do they go to the adjacent countries of the region.

- The other aspect is that due to lack of recognition of CBDM initiatives at the national level, there are often fewer resources poured into these activities.

The CBDM approach acknowledge that as many stakeholders as needed should be involved in the process, with the end goal of achieving capacities and transferring resources to the community, which would assume the biggest responsible in disaster reduction. It should, however, be emphasized that local solution should not be left alone and resources agencies, including government should not take CBDM as a substitute for not taking action.

2.5 Community Based Disaster Risk Reduction Approach

Since development is human centered and reducing disaster impacts involves regulation human action that create the condition in which disaster happen, disasters risk reduction should be seen as a development issue. Incorporating Disaster Risk Reduction concerns into development makes sense for many reasons, including the following:

- The underlying causes of poverty, unsustainable development and disasters are related and all original from factors that cause or increase the vulnerability of people, development with disaster risk reduction concerns can reduce disaster risks, thereby reducing people's vulnerability and contributing to poverty alleviation and sustainable development.

- Disasters can put development at risk and make it unsustainable, thereby reducing the development potential of the country. It is a well-documented fact that for every dollar invested in risk reduction, countries actually save dollars in term of recovery and reconstruction.

2.5.1 The Hyogo Framework of Action

During the world conference in Kobe, Japan 2004, the global community adopted the Hyogo Framework for Action (HFA) as guide in disaster risk reduction.

The HFA has 5 main priority areas in building the resilience of nations and communities to disasters:

- Ensure that disaster risk reduction is a national and a local priority with a strong institution basis for implementation.

- Identify, assess and monitor disaster risk and enhance early warning.

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

- Reduce underlying risk factors.

- Strengthen disaster preparedness for effective response at all levels.

In all the five priority areas the importance of community participation and community-centric disaster risk management is the underlying theme. The HFA also draw the attention to the relationship between development and disaster risk management. Since development is human centered and reducing disaster impact involves regulating human actions that create conditions and vulnerabilities leading to disasters. Therefore, disaster risk reduction should be seen as a development issue.

2.6 Disaster management model

For the community level particularly, Models and schemas help in conceptual simplification. Disaster mitigation and risk reduction offers the greatest opportunity for the integration of disaster management into the development programming process. The prevailing model in disaster management is the disaster management continuum cycle. Its main intent is development, common interpretation tend to focus more on activities immediately before and after the onset of the disaster event. New models, which are relevant to CBDM is Expand-Contract model used in South African communities.

2.4.1 Expand-Contract model

The Expand-Contract model, disaster management is seen as continuous process. Disasters are managed in a parallel series of activities rather than in a sequence of actions. The different strands of activities or actions continue side by side, expanding or contracting as needed.

When it comes to GLOF, immediately after a disaster event, the “relief and response” strand will expand to cope with the immediate effect of the disaster. But as time passes, the “recovery and rehabilitation” strand, including prevention to migration against possible future disaster will expand to address the rehabilitation needs of the affected community. The relative weighting of the different strands will also vary depending on the relationship between the hazard event and the vulnerability of the community involved.

This approach acknowledges that disaster management usually includes a number of intervention and actions that may be occurring simultaneously (at the same time) and not always in phased succession (one after the other).

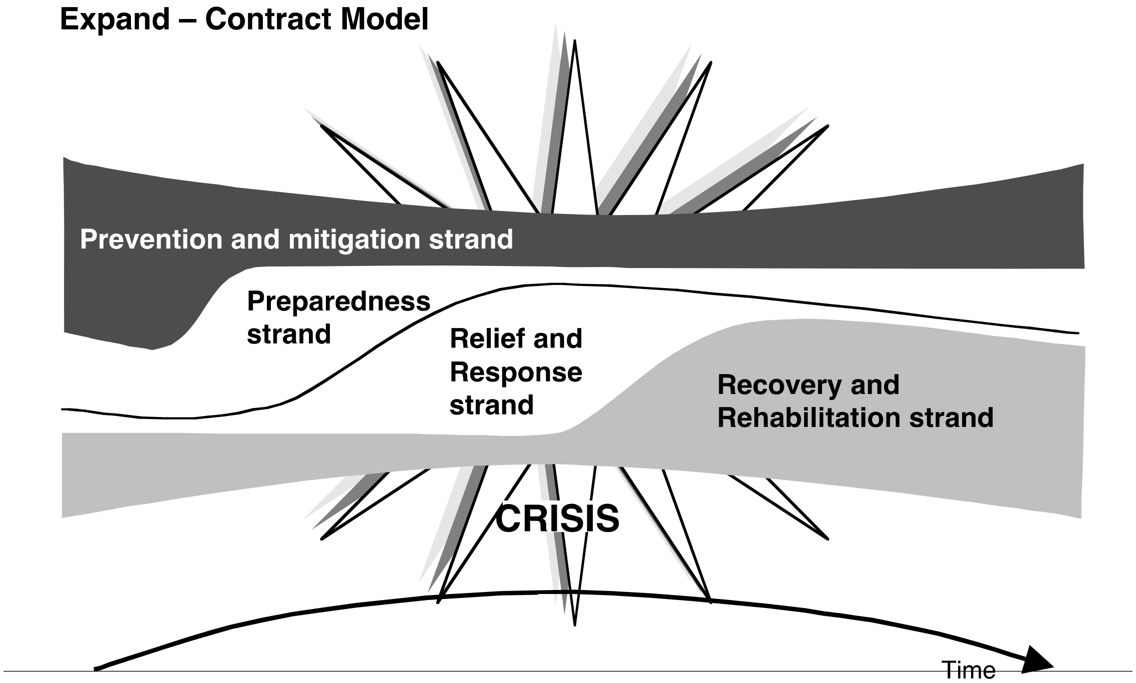

Figure 2.8: Expand and Contract Model, Source: Disaster Management Model

To further explain the model shown in figure 9 above. The Action continues side by side, expanding or contracting on demand. As an example immediately after a disaster the "relief and response strand " will expand. But with time this activity would reduce and the "recovery and rehabilitation strand" will expand. The relative weighting of the strand will vary depending on the relationship between the hazard event and the vulnerability of the community at risk.

2.7 Sustainability Livelihood (SL) Framework

2.7.1 Sustainability Livelihood

What are sustainable livelihoods and how can they be achieved, ideally and practically, can be drawn from several approaches. But while sustainable livelihoods may mean many things to many people, what is common between the various approaches, as noted by Roe (1988), is a call to reduce the complexity and uncertainty that gives rise to demands for sustainable livelihoods in the first place. Sustainable livelihood (SL) can thus be seen as a way of thinking about the objective, scope and priorities for development, in order to enhance progress in poverty elimination.

The definition of livelihood by Chambers and Conway (1992:7-8) which holds that " A livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: a livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the long and short term".

The sustainable livelihoods approach is a holistic approach that tries to capture, and provide a means of understanding, the fundamental causes and dimension of poverty without collapsing the focus onto just a few factors (e.g. economic issues, food security, etc.) in addition, it tries to sketch out the relationship between the different aspects (causes, manifestations) of poverty, allowing for more effective prioritization of action at an operational level.

The assets that are generally recognized with sustainable livelihoods theory, as summarized by McLeod (2001a), are

- **Natural (Environmental) Capital:** Natural resources (land, water, wildlife, biodiversity, environmental resources).
- **Physical Capital:** Basic infrastructure (water, sanitation, energy, transport, communications), housing and the means and equipment of production.
- **Human Capital:** Health, knowledge, skills, information, ability to labor.
- **Social Capital:** Social resources (relationships of trust, membership of groups, networks, access to wider institutions).
- **Financial Capital:** financial resources available (regular remittances or pensions, savings, supplies of credit).

2.7.2 Sustainable Livelihood Framework (SLF)

The Sustainable Livelihood Framework views people operating in a context of vulnerability. Within this context they have access to various assets or poverty reducing factors, which gain their meaning and value through the prevailing social, institutional and organizational environment. Livelihood strategies- the ways in which people combine and use assets in pursuit of beneficial livelihood outcomes that meet their own livelihood objective – are also influenced by this environment. The viability and effectiveness of livelihood strategies is dependent upon the availability and accessibility of assets, services and opportunities, which can be positively enhanced or adversely undermined by ecological factors, social structures or institutional processes. The SLF is able to handle the complexities of local realities, livelihood strategies and poverty outcomes, and the dynamic interrelations between them.

Livelihoods analysis is an important component with regulatory reform. Many of the researchers affirm that the SLF provides a useful conceptual base for understanding urban poverty and the situation of people living in poverty in urban settlements, and is an effective tool for analyzing the impact of regulations of their livelihoods. It can be used to analyze the coping and adaptive strategies pursued by individuals and communities as a response to external shocks and stresses such as drought, civil strife and failed policies and anti-poor regulatory frameworks.

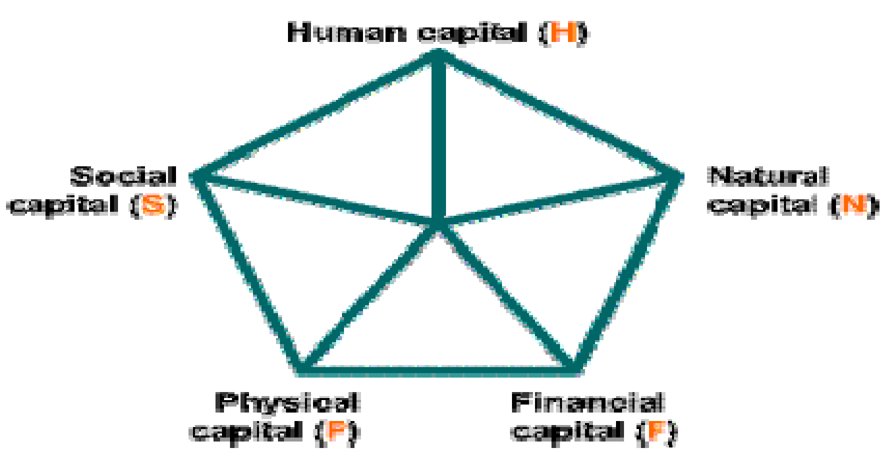

Figure 2.9: Livelihood Pentagon, Source: DFID framework

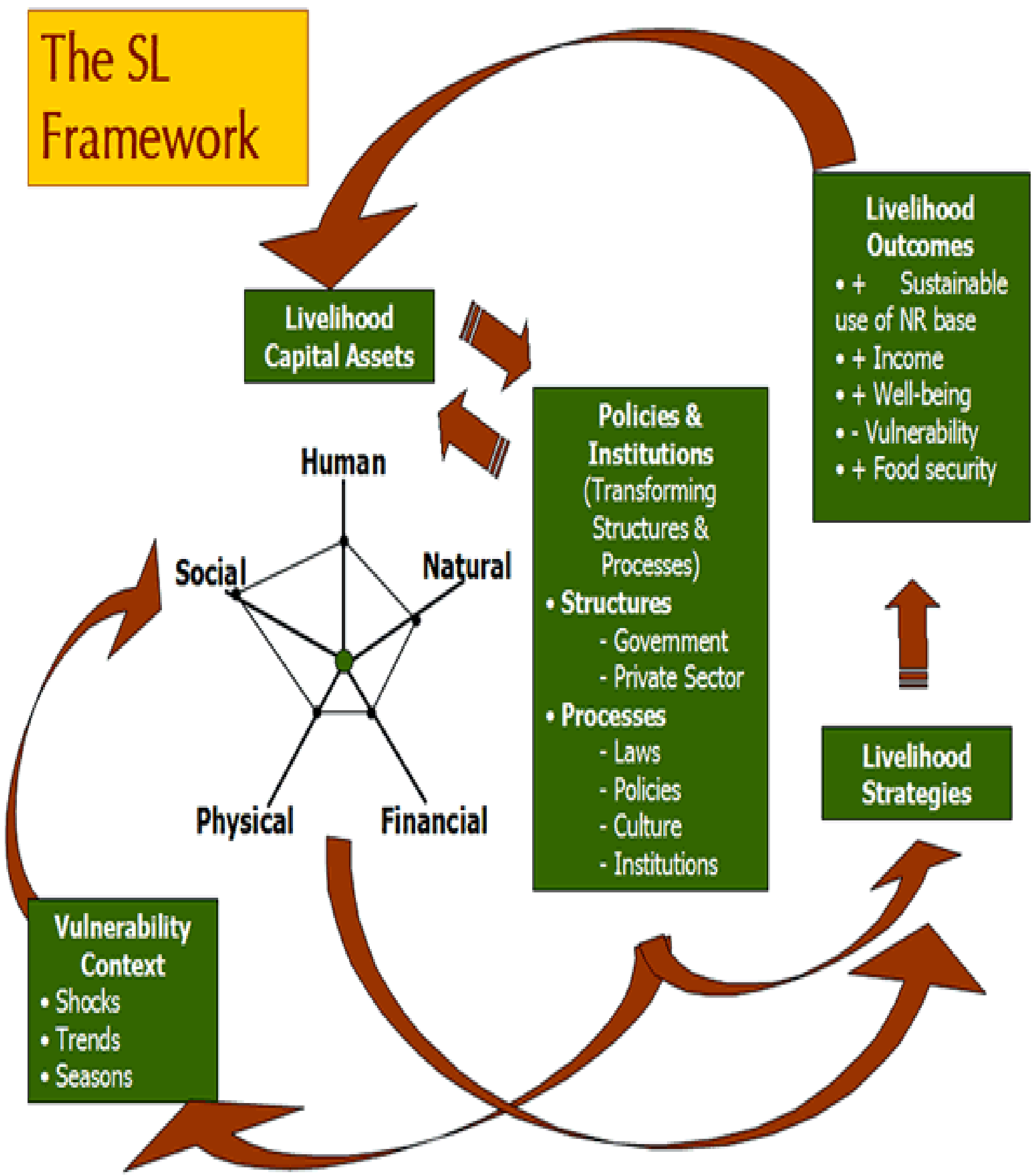

Figure 2.10: Source: DFID framework

2.8 Summary of Selected Important Publications Related to GLOF and Disaster Management in Himalaya Region.

2.8.1 The Impact of global warming on the glaciers of Himalaya – Bajaracharya, Mool and Shrestha, 2007.

Since industrialization, human activities have resulted in steadily increasing concentrations of greenhouse gases in the atmosphere, leading to fears of enhanced greenhouse effect. The world's average surface temperature has increased between 0.3 and 0.6o C over the past hundred years. According to the IPCC, 2001 and their assessments based on climate models, the increase in global temperature will continue to rise during the 21st century.

These changes in climate will inevitably interact with changes in glaciers and glacial lakes. Results show that the recession rate has increased with rising temperature. A forecast was made that up to a quarter of the global mountain glacier mass could disappear by 2050 and up to half could be lost by 2100 (Kuhn, 1993a; Oerlemans, 1994; and IPCC, 1996b). Climate changes is causing the net shrinkage and retreat of glaciers and the increase in size and number of glacial lakes and thereby the frequency of GLOFs in recent years. These changes in climate will have effects ultimately on life and property of mountain people.

- Glacier retreat in China

A long-term study entitled, 'The Chinese Glacier Inventory', by the Chinese Academy of Sciences has reported that during the last 24 years there has been a 5.5% shrinkage in volume of China's 46,928 glaciers, equivalent to the loss of more than 3000 sq. km of ice. The study predicts that if climate continues to change at the present rate, two-thirds of China's Glaciers would disappear by 2050, and almost all would be gone by 2100 (China *Daily,* 23 September 2004). Evidence has been conclusive enough to make glacier melting and retreat an important indicator for climate change. One of the study carried out by ICIMOD in 2004 (Mool et al, 2004) in the Poiqu basin of Tibet Autonomous Region of P R China revealed that the glaciers area has been decreased by 5.04% within 12 years during 1988 to 2000.

- Glacier retreat in India

Earlier studies on selected glaciers of Indian Himalaya indicate that most of the glaciers are retreating discontinuously since post-glacial time. Of these, the Siachen and Pindari Glaciers retreated at a rate of 31.5m and 23.5m per year respectively (Vohra, 1981). Gangotri Glacier is retreating at an average rate of 18m per year Thakur et al. (1991). Shukla and Siddiqui (1999) monitored the Milam Glacier in the Kumaon Himalaya and estimated that the ice retreated at an average rate of 9.1m per year between 1901 and 1997. Dobhal et al. (1999) monitored the shifting of snout of Dokriani Bamak Glacier in the Garhwal Himalaya and found 586m retreats during the period 1962 to 1997. The average retreat was 16.5m per year. Matny found Dokriani Bamak Glacier retreated by 20m in 1998, compared to an average retreat of 16.5m over the previous thirtyfive years. (Matny, L., 2000). The observations also suggest that global warming has affected snow-glacier melt and runoff pattern in the Himalaya. One of the best examples of glacier retreat is the position of Gangotri Glacier snout has been shifted about 2km upward from 1780 to 2001 and is in a continuous process.

- Glacier retreats in Bhutan

Karma et al (2003) found the glacier retreat by 8.1% in 66 glaciers studied from the topographic map of 1963 and the satellite image of 1993. The glaciers area was 146.87 sq. km in 1963 and decreased to 134.94 sq. km in 1993 during these 30 years. The shrinkage of the smaller glaciers has the higher rate than the larger glacier. Some small glaciers of 0.1 to 0.2 sq. km area glaciers are disappeared completely in 1993. Ageta et al (2000) reported remarkable retreat of debris-covered glacier in Lunana basin. Lugge Glacier retreated by 160m/yr. from 1988 to 1993 with the high growth rate of Lugge Tsho Lake, Raphsthreng Glacier retreated 35m/yr. in general from 1984 to 1998 but during 1988 to 1993 the retreat rate was 60m/yr. The Tarina Glacier retreat rate was 35m/yr. from 1967 to 1988. The Lunana basin is the one where series of Glaciers and Glacial Lakes are in the cascading form.

- Glacier retreats in Nepal

The Imja Tsho glacial lake and Tsho Rolpa glacial lakes are expanding about 41m and 66m per year respectively, which is the rate of glacier retreat of respective glaciers. Between 1970 and 2000 during this 30 years period the loss of glacier area was by 5.88% or 0.2% per year in the Tamor River basin of Nepal (Bajracharya et al. 2006). Out of the 2323 inventoried lakes 330 lakes are having the area larger than 0.02 square kilometer and associated with the glaciers. Among them 65 lakes including 15 new lakes are growing in size due to glacier retreat (Bajracharya et al. 2005). Evidences have been conclusive enough to make glacier melting and an important indicator for climate change.

2.8.2 Review of Studies on Glacier Lake Outburst Floods and Associated Vulnerability in the Himalayas – Ghimire, 2004.

- Studies on Glacier Lakes and Outburst Events in Nepal and Bhutan

Works on glacier inventory in Nepal began in the late 60s.The initiation was made by the Japanese Glacier Research Group (1968-1973) and Glaciological Expedition, Nepal (Higuchi 1976). But these studies virtually did not describe about glacier lakes and their outburst events. Some historical data on glacier lake outburst data was presented in the report of Chinese Investigation Team of 1973/74 (Yang 1994). The catastrophic outburst of Dig Tsho Lake in Eastern Nepal on 4 August 1985, 1977 and 1981 (Galay 1985, Ives 1986) made serious disaster and environmental issue to national and international community as well. Much of the studies in the later years were carried on lakes by semi-government institutes including professional consultancies, individual, and students. Studies of Hammond (1988), Yamada (1993), Watanabe et al. (1994-95) describes about the Imja Lake in Khumbu region. From the study of topographic maps, aerial photos, and the imageries, the developments of Imja Glaciers have been reconstructed (Yamada 1993). The lake has increased in size from 0.03 – 0.60 km2 during 1955-1992 (Fig.1). A recent study warns this lake to be potentially dangerous as it is in contact with the tongue of glacier (Mool et al. 2001), which is likely to increase water volume, pressure, and trigger Lake Outburst.

The first glacier expedition made by Gansser (1970) in1960s identified a number of dangerous lakes, which could flood in the lower valleys. He attributed 1957 flood in Punakha Wangdi Valley to the outburst from Tarina Tsho, western Lunana. In 1970s and 80s, joint study team of Geological Survey of Bhutan (GSB) and the Geological Survey of India (GSI) carried out several investigations to asses hazard and socio-economic risk of glacier lakes in Lunana area. These studies concluded that there was no danger of outburst of Lunana Lake in the near future, but recommended periodic checks in every 2 or 3 years, due to presence of ice cores in the moraine dams. The partial outburst of Lugge Tsho located in eastern Lunana, which has affected life and damaged property along the Punakha–Wangdi Valley (Watanabe and Rothacher 1996). Some government agencies of Bhutan carried out research study on cause and effect of outburst and to recommend short and long term mitigation measures (Dorje 1996a, 1996b, National Environment Commission 1996).

In 2001, international institutions like ICIMOD and UNEP came up with inventory of glaciers and glacier lakes, covering entire part of Nepal and Bhutan, based on the study of topographic maps, aerial photos, satellite imagery and literature available (Mool et al. 2001). The study made total inventory of 3252 glaciers with total area of 5332.89 km2. These glaciers contain 2323 glacier lakes with total area of 75.70 km2 in Nepal. Out of them, 20 have been identified as potentially dangerous (Fig. 2). Likewise, in Bhutan, the study found 677 glaciers and 2674 glacial lakes. Total area of glacier was 1316.71 km2 with ice reserve estimated 127.25 km2. Of the total lakes 24 were identified as potentially dangerous.

- GLOF Event's Impact, Vulnerability and Adaptation

GLOF events in the Himalayas not only signify the disaster from flood, but correlate with glacier retreat and global warming trend. The glacier retreat implies a serious concern for water availability for household, agriculture, power and industry for 400 millions living in downstream Indo-Gangetic and Brahmaputra plain. The water demand for agriculture, industry and urban sector in Nepal, India and Bangladesh is progressively growing. The decline in snow cover would mean a condition of water deficit, which is a serious threat to food security, energy availability and industry. In the High and Trans-Himalaya region the decline in snow cover would cause serious impact to mountain ecosystem and the livelihood base of the local people which is based on snow melt water fed agriculture and pasture for livestock grazing

In 1998, the Department of Hydrology and Meteorology, HGM/N under the fund of Netherlands Government, undertook the task of lowering the lake water 3m by cutting an open channel in the end moraine. Likewise in Bhutan as a preliminary stage of planned adaptation to GLOF hazard, studies were carried out since 1970s. Mitigation measures to prevent the bursting of the lake were implemented in 1996 on the Lake Raphstreng Tsho only. In order to lower the risk of flood outburst, the water level of the lake was reduced 4m by excavating channel outlet. In 1999 with an aim to understand more about GLOF hazard, a multidisciplinary approach of assessing geo-risks of the Raphstreng/Thorthormi Tsho area was carried by Austro-Bhutanese Cooperation (Häuslar et.al. 2000), The study concluded that the present day risk for an outburst from Raphstreng is low, but the risk of an outburst of Thorthormi Glacial Lake in the future is considered high. It may occur in 15–20 years if the present trend of climate change continues.

- Glacier retreat, GLOF Events and Climate change

Studies of early 1960s show that the glaciers in the Himalaya have been retreating since the departure of Little Ice Age of the mid nineteenth century (Fushimietal.1980; Yamadaetal. 1992, Ageta et al.1999, Zhen et al. 2003, Karma et al. 2003). Recent observations have shown many glaciers in the Himalayas retreating rapidly. They are considered to be vulnerable to the recent global warming. Yamada et al. (1992) suggests that the retreating rate in east Nepal has increased in 1980s as compared to earlier decades. This accelerated retreat closely confirms to obvious rise in temperature in Nepal since late 1970s (Shrestha 199, Shrestha 2002). Karma et al. (2002) reveals that the percentage of glaciers retreating in India and Bhutan Himalayas ranges between 87 to 100 per cent, while in East Nepal it is 57.3 per cent. The average glacier retreat rate in Bhutan is higher than in east Nepal.

- Average Rate of Glacier Retreat in Nepal and Bhutan

Region	Period (years)	Vertical	Horizontal	No. Of Glacier
Nepal	33(1959-92)	1.72	6.61	58
Bhutan	30(1963-93)	2.23	7.36	86

Table 2.3 Sources: karma et al.2003

2.8.3 Watershed Conservation and management of Glacial Lake Outburst Flood; Combating Climate Change In Himalayan Environment – Dey, South Asia Forum for Environment (Indian Chapter)

The lakes are rapidly filling with icy water as rising temperature in the high mountains accelerating the melting of glaciers and snowfields feeding them. Studies based on topographic maps aerial photographs and satellite images have reported more than 4000 glaciers and glacial lakes in Nepal and Bhutan. The study has revealed a high rate of movement of the retreating glaciers (100-330 feet per year) and also an alarming rise in temperature in these areas (1.0-1.6°C/year). The Tradkarding glacier feeding the Tsho Rolpa glacial lake in Rolwaling valley of Dolakha district of Nepal has a retreating rate of 42 Mts. per year and the lake has grown six fold, from an area of 0.23 sq. Km (1950) to 1.71 sq. Km (1999) due to accumulation of debris and ice-water from the retreating glacier. A GLOF from this lake can wipe out the valleys of Rolwaling, Tamakoshi and the village of Tribeni, which is 108 Km downstream. Such a flood in 1985 from another lake known as the Dig Tsho Lake of eastern Nepal caused a damage of property worth $2.6 million and 9834 human lives

- Bhutan Himalayan Scenario

The Bhutan is located in the eastern Hindu Kush Himalayan range, between 26°45' & 28°20' N latitude to 88°20' and 92°10' E longitude extending from an altitude of 100Mt. to 7550 Mt. above sea level, and has around 677 glaciers feeding approximately 2674 glacial lakes. Only two lakes in Bhutan, Raphstreng tsho and

Thorthormi tsho have been assessed most risky out of all and mitigation work was undertaken. Rest of the 26 lakes is yet awaiting a look over.

Studies have revealed that fast retreating glaciers, are discharging excess water and debris in these lakes, owing to which the lakes are loosing depth, expanding in area and increasing hydrostatic pressure is weakening the natural dam walls making them susceptible to bursting. In fact the rate of change in the size of the lake, geomorphology and morphometric parametric along with trends in the glacial snout displacement are now the key factors for risk assessment. Glacial Lake Outburst Flood not only causes loss of Biodiversity, life & Property in urban area but also spoils agro-environment of watersheds rendering hundreds of marginal farmlands uncultivable. In addition, it causes landslides, communication shut downs, soil erosion and loss, impair vegetation dynamics, force human displacement, etc. even across sociopolitical boundaries.

- Impact Assessment

Ecological Losses are concerned, the most important component of the ecosystem i.e. soil and vegetation has suffered severe damages. Due to sliding and run off, the fertile topsoil is lost or buried. Remixing of slide soil with other soil and debris in the lower watersheds has changed the soil properties. Soil porosity, continuity of soil capillaries, texture and all other related physical characters get altered owing to such remixing (Mitchel 1910). This adversely affects the agricultural crop and vegetation and reduces the retention power and cohesive strength of soil particles. Thus, the area becomes prone to habitat loss unless vegetation cover is stabilized over the affected area. Vegetation, on the other hand, suffers ecological stress as the process of vegetation dynamics breaks. Uprooting of established vegetation and due to burying of the plants many plant species are lost permanently resulting in Biodiversity loss. Seed spread and dispersed seed population loose homogeneity in distribution and also suffer huge loss due to deep burying underneath soil. Agricultural vegetation suffers almost the same way due to down slide movement of earth. Salt wedging and leaching of nutrients in loaded soil change the nutrient composition of the soil (Saxena 1982).

- Socioeconomic Impacts

Owing to downslide movements are more severe and immediate. Since the roads are damaged, supply lines are cut off. Scarcity of bare necessities for sustaining life becomes unavailable. With special reference to Eastern Bhutan, food and medicines were out of reach to people for more than two weeks. The commercial loss, when worked out, stands quite high. In such precarious conditions opportunistic diseases spread in multiple progression, when first aids, too, become unavailable. Nitrate contamination in drinking water and its deteriorating quality was another worsening dimension to health hazards. Assessing the negative impact in agriculture, leads to serious attributes. Farmers suffer loss in production quality and quantity as well. Moreover the event spoils the benefits of crops, multiple cropping and also the field looses fertility (Stone et al 1978). The impact is worst in the remote villages in areas like Tashi Yangtse, Radi and most probably at Moshi. To combat such disastrous situations, the required infrastructure and support is not at all feasible to obtain at hand in any third world country. Bhutan is no exception to it. Thus a sustainable monitoring system and precautionary steps are mandatory in these areas.

2.8.4 Real time Monitoring for Imja Glacial Lake in Himalaya- Global Warming Front Monitoring System - Fukui, Limlahapun and Kameoka, 2009

Twenty-one GLOF events have adversely affected Nepalese territory in the recent past and to date over 200 potentially dangerous glacial lakes have been documented across the Himalayan region. These facts underline the urgent need to enhance scientific knowledge by continuously monitoring glaciers and glacial lakes, developing GLOF early warning system and implementing mitigation and adaptation mechanism. As glaciers retreat, glacial lakes grow. Lake Imja Tsho in the Dudh Koshi sub-basin (Khumbu-Everst region) is one of the fastest growing in the entire Himalayan region. While this lake was virtually nonexistent in 1960, it now covers nearly 1 square km and glows at the rate of 74m per year (between 20001 and 2006) by the survey of International Center for Integrated Mountain Development (ICIMOD). Regular monitoring based on scientific data and information of the lake condition is crucial.

- Real time monitoring system

In November 2007 and April to May 2008, a field survey team from Keio University and NARC installed a unique monitoring device called a Field Server at the end moraine of Lake Imja. A field server serves as a sensor node, which can create a wireless sensor network and simultaneously perform as Wi-Fi hotspot in the field site. The Field Server is a self-sufficient monitoring device, powered supply by batter and solar panel. Data collection is capable in a wide range of sensing data such as hydrological data and current climate conditions. The digital camera then capture the time lapse images at the site. The Field Server at the Imja Lake has been settled and connected to the Internet by means of wireless relay stations, under the collaboration with Asia Pacific Advanced Network (APAN) and NREN.

The merits of the field server are easily understood the real time feature. The circumstances are not only informative to the immediate stakeholders but also other groups who has concerned with global warming and climate change. The facility of the Internet connection technology allow the authorized and experts from ICIMOD and DNPWC to monitor the site real time at anywhere.

- Early warning system

Observation the environment and establishing an early warning system is one of the approaches of this research. An Early Warning system sets the framework for a systematic process of gathering and analyzing data, based on meteorological and hydrological parameters defined by the local organization. Communication of real-time data from the site, Lake Imja, to the early warning center is very critical for generating timely outburst flood warnings.

The study team is also using advances in earth observation satellite technology to monitor the area surrounding Lake Imja as well as pin point other lakes, using techniques such as time series analysis and subsidence monitoring, which have a high potential for outburst flooding. The ALOS satellite, launched last year by Japan and TerraSAR-X also launched last year by Germany provides a number of sensors, both optical and radar based, which are being used.

The use of field based measurements and remote sensing techniques aims to monitor (near) real time situation and establish the early warning system. It is the first-of-its kind in the Himalayan region. Such an early warning system will assist in detecting impending GLOFs to provide more time to relay a warning to vulnerable communities downstream giving them time to move to safer ground. The system is found to be useful to predict the critical situation due to its dynamic approaching and capturing images from the camera from the field server.

2.8.5 Glacial Lake Outburst Floods in the Nepal Himalaya: A manageable Hazard? – Kattelmann, 2002.

Glacial lakes are a common feature at altitudes of 4,500 to 5,500 m in many river basins of the Nepal Himalaya (Figure 1). Such lakes are found behind moraine dams, on the surface of glaciers, within glaciers, and where glacial ice and/or a lateral moraine blocks a side valley (e.g., Ives, 1986; Walder and Fountain, 1997). Moraine-dammed lakes tend to be the most common type in Nepal (Yamada, 1993 and 1998). As glaciers have rapidly retreated during this century (e.g., Rothlisber- ger and Geyh, 1985; Yamada, *et al.,* 1992; Evans and Clague, 1994), basins are created within the evacuated space between the retreating glacier and the lateral and end moraines. At the same time, melt-water ponds often form on the debris- covered snouts of these glaciers. These ponds may enlarge and coalesce into glacial lakes that lie on top of and adjacent to stagnant ice. As the glacier retreats and the lake grows, this so-called dead ice may both constitute part of the impoundment along with moraine material and contribute to the volume of the lake as the ice melts.

At their extreme, glacial lake outburst floods can release millions of cubic meters of water in a few hours. Instantaneous discharges can be up to thousands of cubic meters per second. Obviously, such discharges have enormous power and the potential to do considerable geomorphic work. Large amounts of moraine material are initially entrained as the dam is breached. Although much of this material may be deposited in the first few hundred meters downstream, the flow is likely to become hyper concentrated with particles from the moraine itself and the valley floor and side slopes.

Although glacial lake outbursts have obviously helped shape the Himalayan land- scape over time, outburst floods in the eastern Himalaya were rarely mentioned in the western literature (e.g., Muller, 1959; Gansser, 1970) until the past two decades. In 1956, a large flood ascribed to a glacial lake outburst left 40,000 people homeless in the Indrawati valley, and a small glacier lake outburst flood occurred in the Imja valley (Muller, 1959). Occurrences of seven other outburst floods in rivers of eastern Nepal between 1935 and 1970 have been inferred from historical analyses (Yamada, 1998). An outburst flood in 1977 in the Khumbu Himal was recognized in the record of a stream gaging station 60 km downstream, and was the first event in the region to receive much scientific study. This flood originated from a series of lakes on and below the Nare Glacier in the Mingbo Valley west of the summit of Ama Dablam. Imagery from the LANDSAT Multi-Spectral Scanner before and after the event indicated that a small lake at about 5,160 m drained into a much larger proglacial lake and another smaller lake and caused the release of about 4.9 million m3 of water (Buchroithner *et al.,* 1982). Another study of this flood estimated that only about 400,000 m3 of water was released and that the initial failure was caused by melt of an ice-cored moraine (Fushimi *et al.,* 1985). Nevertheless, channel changes in the Imja Khola and Dudh Kosi were extensive, and parts of river terraces collapsed tens of kilometers downstream.

These various assessments have generally regarded four lakes to pose the greatest risks in the near future: Tsho Rolpa in Tamba Kosi river basin, Imja in Dudh Kosi river basin, Thulagi in Marsyandi river basin, and Lower Barun in Arun river basin. The International Centre completed a more exhaustive study in September 2000 for Integrated Mountain Development that inventoried 2,315 glacial lakes in Nepal and 2,674 glacial lakes in Bhutan. The study assessed the risks posed by these lakes and identified as “potentially dangerous” 26 lakes in Nepal and 24 in Bhutan.

The communities need to make the first steps by seeking and distributing in- formation about the upstream hazard. Although outsiders can catalyze and assist this effort, local leaders must direct the community decision process. A couple of dedicated leaders could make a significant difference in stimulating the decision process and, if chosen, soliciting technical and financial resources. Thorough discussions of the natural risks and those of inaction and alternative actions are necessary. Although the affected communities may choose to continue to live with the hazard, such a choice should be a deliberate decision made with as much information as is available, rather than avoiding or delaying a decision.

Because Nepal lacks the financial capacity to deal with the glacial lake outburst hazard, external funding will be necessary. Some fraction of the foreign aid pro- posed for various water resources development projects could be directed toward reduction of this water-induced hazard. Billions of US dollars have been spent in recent years on recovery missions following various natural disasters. Here is an unusual opportunity to reduce the possibility of disasters before they happen at relatively low cost rather than reacting to another calamity. Unfortunately, the problem was not addressed during the United Nations' International Decade for Natural Disaster Reduction, though it should have been an obvious candidate project. Perhaps global visibility for glacial lakes can be obtained during the 2002 International Year of the Mountains.

2.8.6 Natural dams and outburst floods of Karakoram Himalaya – Hewitt 1982

The Karakoram Himalaya and neighboring ranges, there has been a substantial number of these main valley glacier lakes in modern times. Outbursts from a series of dams on the Upper Shyok between 1926 and 1932 brought devastating floods along more than 1200 km of the Indus. Some even larger landslide dams and outburst floods occurred here in the nineteenth century and an exceptional concentration of surging glaciers has been found (Hewitt, 1969, 1975, unpublished). Some of the latter have formed main valley ice dams.

Thirty-five destructive outburst floods have been recorded in the past two hundred years. Thirty glaciers are known to have advanced across major headwater streams of the Indus and Yarkand rivers. There is unambiguous evidence of large reservoirs ponded by eighteen of these glaciers. Meanwhile, a further thirty-seven glacier interferes with the flow of trunk streams in a potentially dangerous way. There is geological evidence of other dams and numerous reports of glaciers across main river channels, which they were not actually damming.

The Karakoram and other high ranges have 60-70% permanent snow and ice covers. Snowfall of the order of 1000-1500 mm water-equivalent is indicated here. Yet valley floors, lesser ranges and the eastern plateau remnants are generally arid or semi-arid. In addition, strong aspectual differences of climate greatly influence the glacier cover and glacier behavior.

Breaching of a dam creates a sudden short-term increase in discharge downstream. If breaching is catastrophic, as so often in the Karakoram region, the impact of the flood wave can far outweigh that of other high flows. In part, this can involve a concentration of flow in the upper reaches of the rivers well in excess of weather-produced extremes of runoff.

The 1929 outburst flood of Chong Khumdan Glacier was monitored from near the glacier over more than 1500 km downstream (Gunn, 1930; Mason *et al.,* 1930). Gunn, (1930) estimated the reservoir to have contained almost 13.5 X 10x8mCube (1.1 million acre feet). Some 3X10x5mcube of ice water also carried with the flood and stranded on large blocks in the valley below the dam. The mode of dam failure is critical to the size and shape of flood wave. All we know of the 1926, 1929 and 1932 Khumdan outbursts is that breaching began through sub glacial tunnels, but then carried away the entire thickness of ice above.

The flood peak was highest at Sasir Brangsa, but the 1929 wave showed remarkable recuperative power in the Indus gorges, below Skardu. The effect is the same as in the well-known Johnstown, Pennsylvania flood disaster of 1889. As the floodwaters gather in, and then leave intermountain basins such as at Skardu, they re-enact a pseudo-dam break.

The significance of these floods lies especially in the exceptional risk to human communities or installations, and also in their role in erosion and sedimentation. Over much of their course in the mountains, the recorded floods reach heights well above peak discharges from summer melting. Their dynamic character greatly magnifies their erosional competence and capacity. These two matters are of singular importance in the erosional context of the Karakoram valleys, and sediment transport into downstream reservoirs.

Sediment yield from the Upper Indus Basin represents the highest known rate of regional erosion over such an area, of about one meter per thousand years (Hewitt, unpublished). In the event of a phase of recurrent damming such as occurred prior to 1940, these erosional events could increase the rate of sedimentation in artificial dams on these rivers, and reduce their economic lifetimes.

2.8.7 Snowmelt Runoff Modeling in a Basin located in Bhutan Himalaya – Jain, Lohani and Singh, 2012

Modeling of stream flow from a basin is based on transformation of incoming precipitation to outgoing stream flow by considering losses to the atmosphere, temporary storage, lag and attenuation. In most part of the world, the seasonal short-term variation in stream flow reflects the variation in rainfall. But in higher latitude and altitudes where snowfall is predominant, runoff depends on heat supplied for snowmelt also rather than just the timing of precipitation. Hence, to understand the hydrological behavior and simulate the stream flow in such area, it is very important to model the snowmelt runoff.

Satellite images were extensively used for snow study in Himalayan condition by several researchers. Dey and Goswami (1983) used NOAA-VHRR data to predict seasonal snowmelt runoff in Indus basin. Saraf et al., (1999) has used passive microwave (SMMR) data for snow-depth and snow-extent estimation in a part of Satluj basin in the Himalayan Mountains. Rango, (1996) has analyzed and reported that NOAA-AVHRR and Aqua/Terra-MODIS data are useful for snow study with basin area above 200 km2. Gupta et al., (2005) have used Indian Remote Sensing satellite (IRS) LISS-III multispectral data to map dry/wet snowcover in Himalaya. Besides, many researches were conducted on snowcover study in Himalaya using satellite data The revolutionary role of remote sensing in snow study is discussed elaborately by Rango (1996), Hall et al, (1995), Jain (2001), Singh and Jain (2003) and Jain et al. (2008).

There are several temperature index based snowmelt models like the SSARR Model, the HEC-1 and HEC-1F Models, the NWSRFS Model, the PRMS Model, the

SRM, the GAWSER Model. The Snow Melt Runoff (SRM) model is widely used for snowmelt modeling in Himalayan basin. The SRM uses snow-covered area as input instead of snowfall data, but it does not simulate the base flow component of runoff. In other words, SRM does not consider the contribution to the groundwater reservoir from snowmelt or rainfall, nor its delayed contribution to the stream flow in the form of base flow, which can be an important component of runoff in the Himalayan Rivers, and plays an important role in making these rivers perennial. Almost all the stream flow during winter, when no rainfall or snowmelt occurs, is generated from the base flow (Jain, 2001, Singh and Jain, 2003).

The four major rivers of Bhutan i.e. Ammochu, Wangchu, Sankosh and Manas all of which flow in north-south direction with numerous small rivers and streams as tributaries, discharge into the Brahmaputra River in the plains of India and Bangladesh. The largest among these is the Manas, which has four major tributaries: the Gamrichu, the Kurichu, the Chamkharchu and the Mangdechu. The Chamkharchu River has its source from the glaciers of Gangkar Punsum and the Monla Karchung ranges. The Chamkharchu emerges from the glaciated terrain south of the water divide separating Tibet from Bhutan's northern territory. It has one western branch and two eastern branches. The western branch has its source from the glaciers of the Gangkar Punsum region and the eastern branches have their sources from the glaciers south of the Monla Karchung La Range.

The runoff from snow covered area consists of: (i) snowmelt caused due to temperature, (ii) under rainy conditions, snow melt due to heat transferred to the snow from rain, and (iii) runoff from rain itself falling over snow covered area. The source of surface runoff from the snow free area is rainfall. Like snowmelt runoff computations, runoff from snow free area was also computed for each zone. The entire data base has been prepared for four years i.e. 2004-2005, 2005-2006, 2006-2007 and 2007-2008. In first phase, the model is calibrated for two years (2004-2005 and 2005-2006) for the catchment up to Kurjey site for two years (2006- 2007 and 2007-2008) for this catchment. Hydrological models are generally calibrated using computed and observed stream flow records, while the available data set is split into two parts: one being used to calibrate the model and the other being used to validate it, i.e. to check how the model performs in simulation mode (Blackie & Eles, 1985).

After successful calibration of the model for a period of two years, the model was run to simulate daily streamflow up to Kurjey site using independent data for two years (2006-2007 and 2007-2008). The comparison of daily observed and simulated streamflow for these two years is shown in Fig. 4. The overall efficiency of the model over the study period of two years was 0.91 and 0.90 for 2006-07 and 2007-08 respectively and the difference in volume of computed and observed streamflow was only 9.17% and 1.62%. The results indicate that the model performed equally well for the simulation years as for the calibration years.

The model was calibrated for the catchment up to Kurjey site using data of two years (2004-05 and 2005-2006) and then used for simulating the daily stream flow for an independent data set of two years (2006-07 and 2007- 08). The model was also applied to estimate the contribution from snowmelt and rainfall at the project site. The analysis suggests that about half of the flow comes from rainfall runoff.

CHAPTER 3
METHODLOGY

3.1 Research Design

Glacier Lake Outburst Flood is amongst the most serious natural disaster in Bhutan Himalaya. GLOFs are product of Global warming and climate change. GLOFs are being taken as serious issue and options for adaptation are being developed. " Local community is taken as the primary focus of attention (in disaster reduction) since that the is common unit which is affected by disaster and, more importantly, responds to deal with the event."- Russell Dynes. Keeping and recognizing above fact the topic was chosen to explain one of major GLOF disaster through CBDM. The research will be start by preparing extensive literature review, there will be draft questionnaires prepare and will be tested in the field in prior to the survey.

There are uses of some of the relevant models to help in conceptual simplification in explaining GLOF disaster at community level. Some of the model use is The Disaster Risk Management Cycle and Disaster Crunch and Release Model.

The research proposal will be discussing with personnel and local stakeholder who is going to help in planning the fieldwork. Data during the field visit are going to collect using Participatory Rural Approach and methods are adopted form DFIDs sustainable livelihood guidance sheet.

3.2 Review of relevant literature and information

In order to broaden and have better knowledge of the concept of GLOF disaster and CBDM study, relevant report and documents will be reviewed. For better understanding and assimilations in GLOF disaster risk management relevant model are used, like Disaster Risk Management Cycle and Disaster Crunch and Release model.

To get good result of the secondary information collection review, Climate and GLOF related data like temperature, rainfall, glacier melting, population and meteorological related with research study were collect from Department of Geology and mines and Department of Disaster Management.

3.3 Selection of Study Area

The study area chosen for study of Community Based Disaster management on GLOF disaster were along the Pho Chu at Samdingkha village under Punakha district. And most of the population of Samdingkha community lives along the bank of Pho Chu. And this community had experienced three GLOF disasters and was badly hit by 7th October 1994 GLOF.

3.3.1 Geographical Location

Punakha Dzongkha is in northern part of western Bhutan, with 12 of gewog and 48 villages. The Samdingkha village is situated in northeast of Punakha Dzong and has an elevation of 3000 to 4000 meters as shown in figure 3.1, 3.2, and 3.3.

3.3.2 River system

Samdingkha village is located along the bank of Pho Chu. The sources of Pho Chu are from three-glacier lake in Lunana region. Pho Chu had got two tributaries at sources- a Western sources by Tarina glaciers and eastern branch by the Lunana glacier including three glacial lakes. Pho Chu meets Mo Chu at Punakha Dzong where it stand as confluence of these two mighty rivers as shown in figure 3.4, after that this river is called as Puna Tshang Chu and becoming the longest liver of Bhutan, covering 6 Dzongkha with roughly measuring 250km.

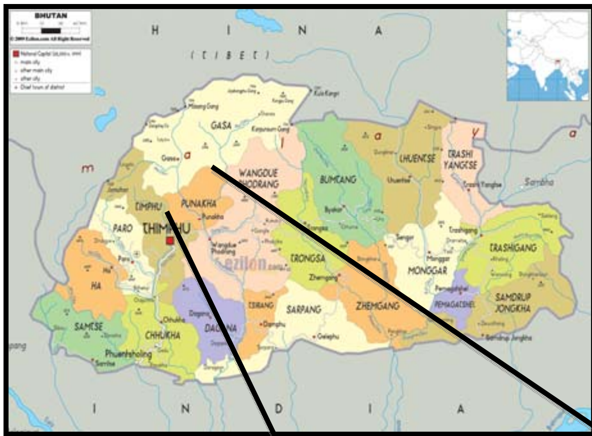

Figure 3.1: Punakha District in Map in Bhutan, Source: mapsofworld.com accessed on 13th Oct. 2012

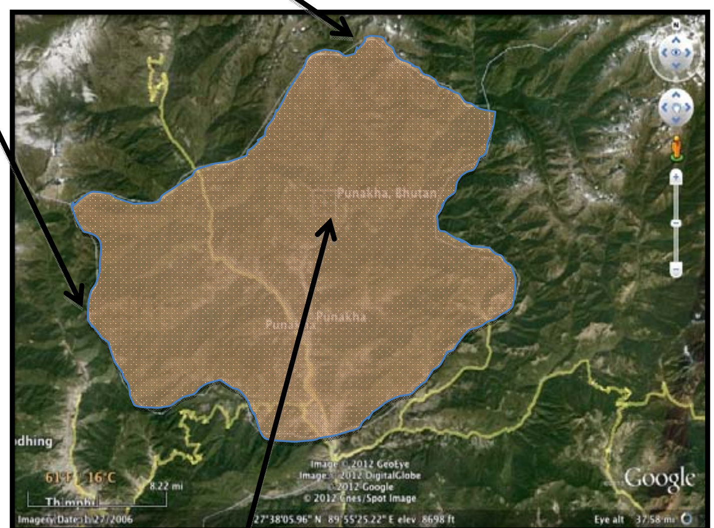

Figure 3.2: Punakha district, Sources: Google Earth, Oct. 2012

Figure 3.3: Samdingkha location, Sources: Google earth, Oct. 2012

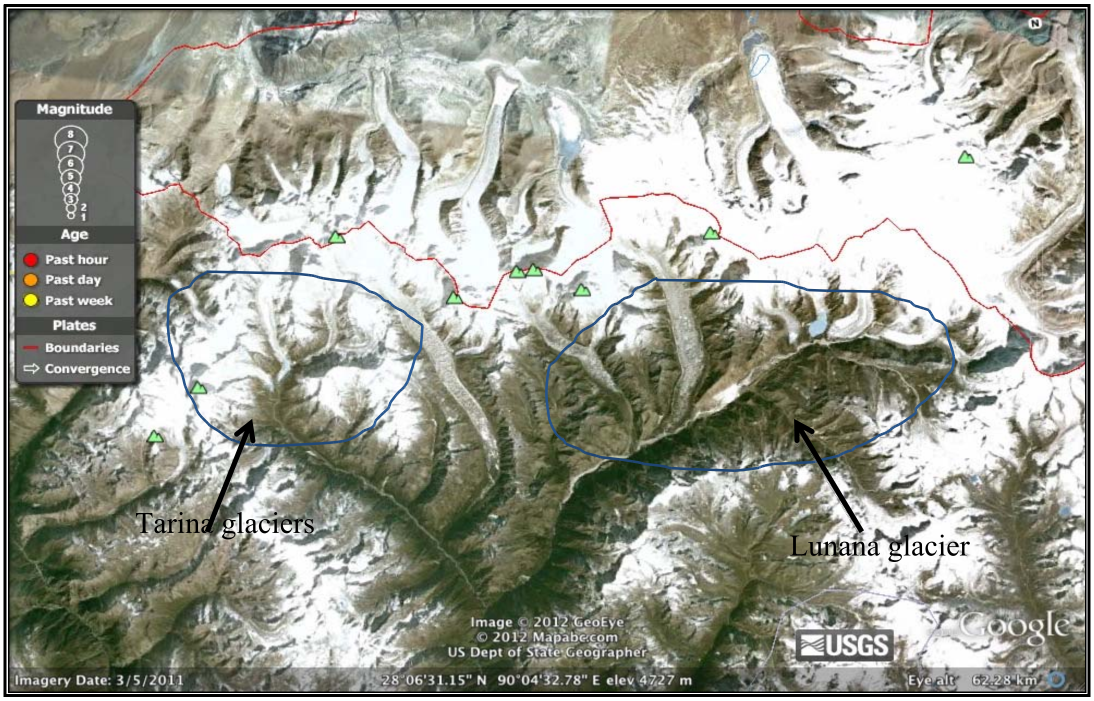

Figure 3.4: Source of Pho Chu, Sources: Google Earth, Oct. 2012

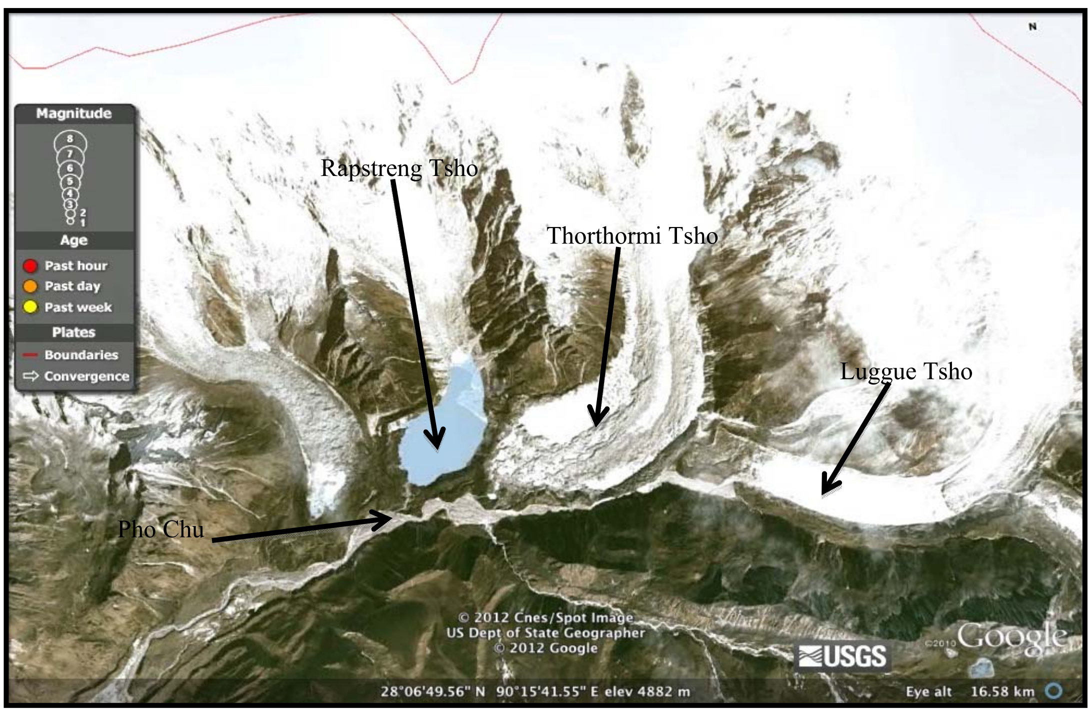

Figure 3.5: Glacier lake overhead of Pho Chu, Sources Google Earth, Oct. 2012

3.3.3 The Glacier lakes

The head of Pho Chu are one of most dangerous glacier lake of Bhutan. They are Luggue, Thorthormi and Rapstreng Lake as shown in fig 3.5.

- **Luggue Tsho -** The Luggue glacier lake breach in 7th Oct 1994.

- **Rapstreng Tsho** – Its one of the biggest lake and Mitigation measure were taken by reducing the lake water level by 4 meters in 1997- 1998. The potential of outburst is indicate low.

- **Thorthormi Tsho –** Risk of outburst is considered High. Outburst of one Glacier Lake could trigger another as these 3 glaciers lake lie near to each other with weak moraine. The potential of outburst is high if any one burst.

3.3.4 Past History of GLOF disaster

Bhutan had experienced 3 GLOF disasters and all of them were in Pho Chu. The valleys along the Pho Chu have experience and witness GLOF events. The 3 GLOF disasters are in 1957, 1960 and 1994.

3.3.4.1 the 1957 and 1960 GLOF

The 1957 and 1960 GLOF disaster have got very no written records. During 1970 expedition by Gansser attributed the 1957 GLOF to the outburst of Tarina Lake, and it was later conformed in a geo-morphological study of the area by Leber *et al* in 2003. 1960 GLOF disaster was from the eastern Lunana lakes. As a result of both GLOF disaster have damaged the Punakha Dzong very badly.

3.3.4.1 1994 GLOF

On 7th Oct 1994 from the partial breaching of the Luggue lake with 18 million cubic meters of water outburst. This GLOF disaster have engulfed may many lives, destroyed 12 houses, 91 household affected, 5 water mill washed away, 4 bridges and more than 1000's acres of land destroyed and Punakha Dzong damaged, where by causing property losses wroth million of dollars.

3.3.5 Seismicity

The Earthquake hazard can trigger easily the inherent instability of moraine or ice dam and by making lake outburst. Western Bhutan lies in earthquake zone 4 and Eastern Bhutan in Zone 5. For the first time, Hazard zone in the event of an earthquake were shown by the Indian institute of technology in Rourkee, India has done a seismic hazard map of Bhutan as shown in figure 3.6.

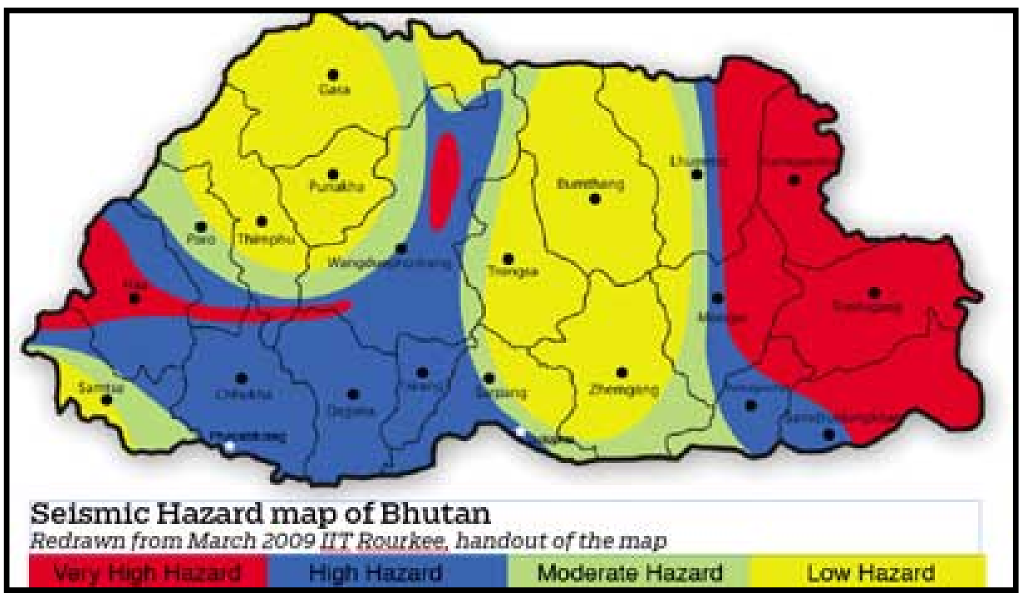

Figure 3.6: Seismic Hazard Map of Bhutan, Sources: Kuensel, 2012

As so far in Bhutan there is no record of GLOF disaster, which had been triggered by Earthquake hazard. But the latest earthquake hit Bhutan was on 21st Sep. 2009 at epicenter in Mongar Dzongkhag with magnitude 6.1. At least 12 people killed and dozen injured in Mongar and Trashigang Dzongkhag due to collapsed buildings. Many buildings destroyed and many roads have been damaged.

3.3.6 Communications

The study area is connected with road route from Punakha Dzong. As the entire areas are connected with non-metaled roads; Public buses and motor vehicle are available for local transportation.

3.3.7 Vegetation and Land Use

As the study area is located in mountainous terrains, which limits the expansion of agriculture. Most of the fields are good for rice cultivation and people take advantage at fullest. Cash crop are almost grown almost everywhere and farming practice have strongly influenced the present vegetation.

3.3.8 Reason for choosing this study area

1. The past 3 GLOF events, which occurred in 1957, 1969 and 1994, flooded the valley.

2. 1994 GLOF has impacted people of this village very badly.

3. A few research of community Based had been published, this research will also provide additional information for comparative studies.

4. Outburst of glacial lake not only threatens the socio-economic development like tourism, transportation, agriculture and sustainability at the downstream but also huge losses of lives of people.

3.4 Source of Data collection

For any research study it is an important to collect and gather the data. To analysis, research, planning and management, data collection play paramount role. The sources of data for this study are of primary data and secondary data. Collecting primary data from the respondent (PAR method) and satellite data will assess the current impact, Vulnerability, Risk and livelihood of community. Secondary data are temperature, rainfall, glacier melting, government documents, meteorological data, and published and unpublished information.

I have collected valuable information on impact of GLOF hazards at downstream communities as field observer. I have visited the village and got some ideas about the people's perception about the knowledge in risk about flooding. Communities are aware about non-structural mitigation efforts with the help of Dzongkha Disaster Cell. I have casual conversation with many people; I had been feed with information about Chronology of the glacier lake, installation of early warning system (Siren system) at risk places along the valleys, identification of evacuation site (safe zone) as if flooding happen, and there had been mock drill of evacuation in times of flooding. The most important information I learned not theoretically but practically that community had shown me danger zone and safer zone of GLOF hazard.

3.4.1 Satellite Data

Some satellite image was acquired mainly focusing some of glacier and Glacier Lake also study area.

3.5 Selection of site for PAR

The study was conducted in Samdingkha village in Punakha Dzongkhag as shown in figure 14. Samdingkha village settlements are located on the left bank of Pho-Chu on alluvial terrace of 3m to 4 m high from the river. Most of permanent and semi-permanent buildings are constructed on low-lying alluvial plain. Selection of the site are selected in discussion with my supervisor keeping in mind the most affected sites and a risk community exposed towards disaster were chosen to fulfill and achieve the focus of the study.

The following tools were used selection of PAR methods

3.5.1 Building Rapport with local level stakeholders

Preliminary meeting will be organized with local level stakeholders to share the purpose of the study. It was useful to select the study community and clusters within the community.

3.5.2 Interviews (Focus Group Discussion, Key Informants)

The interview schedule (Appendix A to E) consists of questions. The parts A are general and seek information mainly about the demographic and geographical characteristics of the respondents and their village. The part B Social mapping and question were designed to ease the conversation and have better picture about the village community and development. The part C Vulnerability issue comprising set of issue where community can easily understood the statistics of vulnerability ranking. The part D and part E consisting of question, was intended to gain insight into the level of knowledge of the respondents about GLOF disaster and risk perception. There are also question on people's awareness on global warming and policy recommendations.

In order to validate the information from the discussion with community KII was done with the different government line agencies at the district also with NGO's working in the community. Unstructured interview was done to verify the answer.

3.5.3 Transect walks

This walk was used as method to be familiar with the area and the people that were mostly affected from the flood. This exercise was also useful to assess the land use pattern of the study community.

3.6 Data Analysis Procedures

There will be two major part in this research study beside many sub parts, there will be quantitative study on GLOF disasters and community based disaster management and Vulnerability and Risk of Samdingkha community of Punakha district through filed study will be more qualitative in nature. At the end of study there will be given some recommendation for the future intervention in that particular community.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Social Mapping

The Samdingkha village is one and half hours drive from the Punakha Dzong. The village is located on left side of Pho-Chu. Elongated land with very fertile soil and it is main commercial hub in and around adjoining village. Village is connected with un metal road. But it make little difficult to for plying of vehicle during the rainy season. But the good advantage point is that village do have olden days horse route, which make the people assessable easily to neighboring towns and villages. The socio-economic condition of the people is not that dad due to relative and families' member having job in cities and town, where they help with finical support. Majority of people they work in field and are self-content, only Grocery item they buy from shop. Both men and women work in field and raise cows. Main earning sources are rice and cash crop, which include oranges, guava, sugarcane and chilies. Agriculture is the main sources of self-sufficient and income. They sell rice and cash crop in local market and cities market. Rice is cultivated once in year and cash crop yield once in year too. During 1994 GLOF, flooding water has entered almost all fields with sand, rocks and debris. After the floods villager had difficult time in cultivation of crops due to sand and rocks covering their fields. This had serious affect the yield of crops on this same year of flooding.

Figure 4.1: Bird eye view of Samdingkha Village as on 17 Oct. 2012 (photo by author)

Figure 4.2: Villager drawing Recourse mapping (Photo by author)

Figure 4.3: Transect walk (Photo by author)

When it comes to water and sanitation condition it's well organized and they have got few water tank, which is maintain by the villagers themselves. Each and every house is connected with piped line water tap. The sanitation system in the village is hygienic, as most of the house have got toilet maintain properly only few of them, they have got open toilet. Village has primary school, where children of village are easily accommodated, and for secondary education they are send on boarding school in their own district. Due to free primary education and easily available school there is not children deprived of education. One of elder man of village said " *as all the children goes to school, there is lack of helping hand working in the field, this is only problem we got, but we believe education is very important even though we face lot of challenges of man power. We still send our children to school for their better and educated village".*

In Samdingkha village maximum houses are permanent structure made of beaten mud with wood and the few roof with tin sheet and wooden sheet. And few houses and shops are semi-permanent structure made of wooden plank and tin sheet as roof. And maximum shops are in red zone. In same context, I asked few shopkeepers why they prefer to settled, build house and shop in river valley, why not up-hill? They told me " *At river valley soil are fertile, land formation are plain, road net work and most of the people get-together in river valley, which make our trade business very successful and also very easy for establishing the business".*

When health service is concern there is one basic health unit in the village, but without doctor and its run by health assistance. When serious and complicated cases arise they refer to general hospital at Punakha, which is one and half and hour drive. Usually villagers suffered from Diarrhea, skin disease, dysentery and other diseases.

Communication especially in the rain season is big challenges in the village because it is un-metal road. The major transport of the village is taxi, light vehicle and trucks, where villager takes their goods for sale in market in public transport.

As the Samdingkha village is very prone to GLOF. There are three-evacuation site identified in the village with route earmarked in times of GLOF disasters. According to one of villager told me " *they have practice few times mock drill to escape at evacuation site in earmarked route in times of flooding disaster"*.

In village there is one forest office and RNR office.

4.2 Resource mapping

Recourse mapping means a map, which depicts resources of the entire village area mostly natural resources. Resource mapping helped us to draw a map of natural resources, which is used as livelihood assets in Samdingkha village. Mapping was done with help of five DFID livelihood assets as shown in the diagram below.

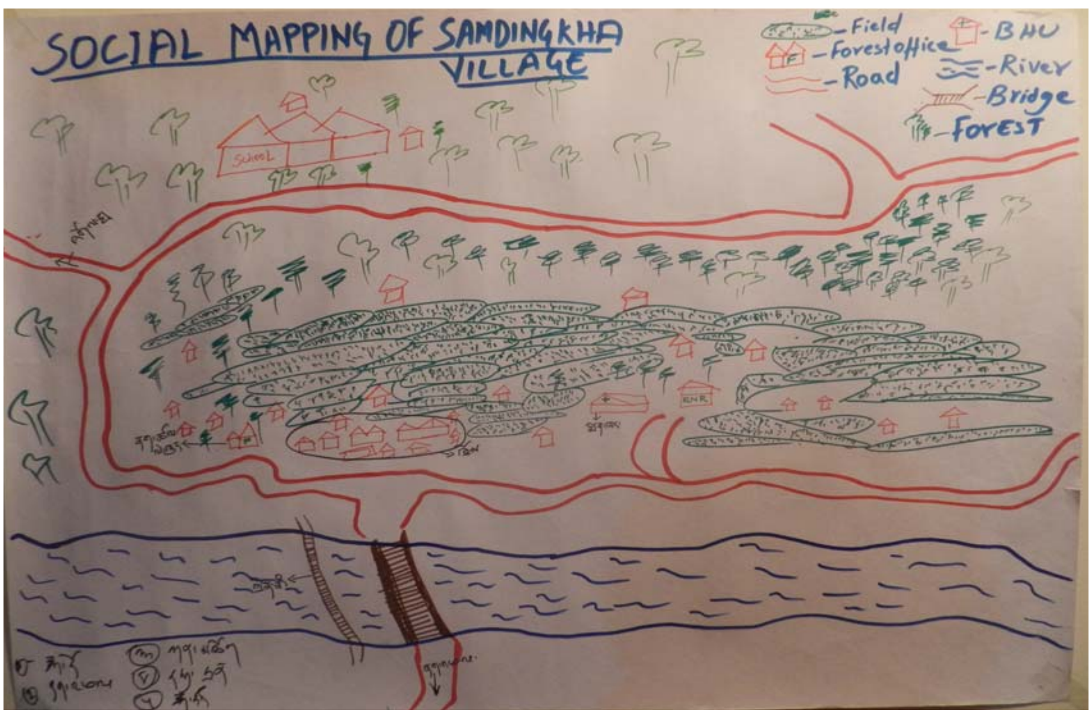

Figure 4.4: Social mapping of Samdingkha Village as on 17th Oct. 2012

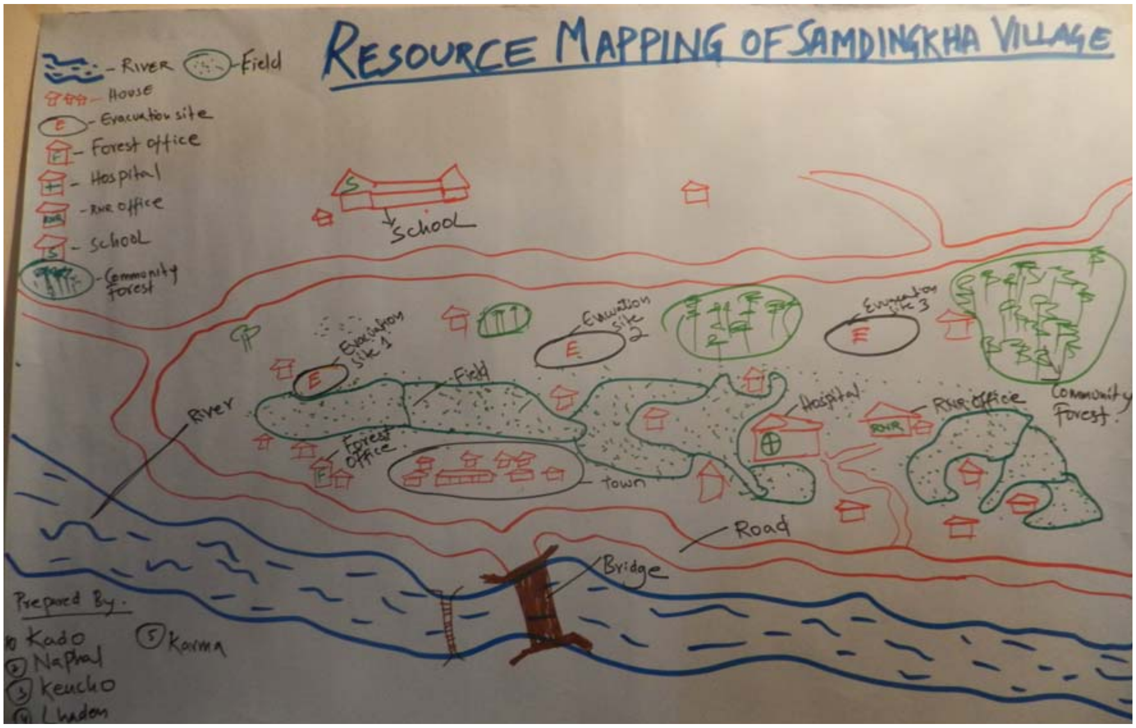

Figure 4.5: Resources Mapping of Samdingkha Village as on 17th Oct. 2012

4.2.1 Human Capital

Communities of Samdingkha village have good knowledge of GLOF hazard and they had adapted themselves as they had experience three GLOF events. The Human capital in Samdingkha is worked out or represents by the occupation, health facilities, education facilities, house structure and Skill and Knowledge.

In Samdingkha village there is one primary school as it is their main sources of education. Where not only the village children are studying even the adult person who had not got the chance to study in their early life, they are given non-formal education in the same primary school. And the same school is also used as GLOF disaster shelter. Building structure of the school is permanent structure and it's out of danger zone of GLOF hazard.

When it come to health facilities for the villagers, there is one basic health unit with no doctor but they have health assistances and others staff working. In case of complicated case BHU refer them to Punakha hospital. Health resources in the village are well maintained, but still villagers are suffering from high fever, acidity, dysentery, common cold and diarrhea.

In the village, majority of house structure are made of beaten mud with strong wooden block and tin and wooden plank as roof. And there are few semi permanent houses.

And when it comes to occupation of the community, majority of men and women are farmer working in field and only few of them are running shops. In Samdingkha village there are about 12 shops.

4.2.2 Natural Capital

As agriculture being main sources of livelihood for Samdingkha village Rice and wheat cultivation is done only once in year. So due to this reason they really need to work hard in the particular crop seasons. The interview and discussion with the villagers reveals that they just pray to god that GLOF disaster not to come before harvest and also after the crop plantation. Otherwise for whole years their will be no food security for them.

They don't have huge forest cover but they do have community forest. Where they collect firewood and use as cattle grazing for pasture. They collect manures and dry leaves and twigs for making animal warm. Community forest is helpful for village but it provide the wild animal like wild boar and monkey, which destroy the hard work of the villagers.

4.2.3 Social Capital

Social relationship in the village is very good. In Samdingkha village neighborhood and village hood relationship are extremely good. They help each other in times of building house and during peak cropping season by rendering helping hand. The past GLOF event had clearly shows, that community they help each other with labor and financial in rebuilding homes and bring back to normal life.

The social resources are being benefits received from the government. When it comes to GLOF hazards government have increased the capacity of the villager by bringing the people together with training. Help the community with mock drill in times of GLOF event. Government has given the villagers with shelter and relief facilities. Not only that government and local government have been actively participating with community in reducing risk of GLOF hazard where by give them social security.

4.2.4 Physical Capital

The location of Samdingkha village is vulnerable to GLOF disaster, though there are embankment build in some of the prone area but those embankment is just to reduce the loss. Transport network is well connected in and around the village. but the route to the evacuation site is foot path not mortar able road, which makes loss of asset in bulk transportation. As they get enough time for preparation of evacuation because they are well connected with both manual and automatic early warning system, if the GLOF event starts.

In village there are three-evacuation site, but those safer area are in open air. Those open air don't provide any guarantee for safety of assets own by individual family. There is no roof for the safer site, if the flooding happens during the rainy season, which will lead to huge loss of assets and problem for the people.

Location of all the 10 shops are just at the bank of the river, where housing structure are all made of very weak material like wooden plank and mud as wall with tine sheet as roof. Basically it can be termed as semi permanent structure. And more over there is community vegetable market just at the bank of river, I was told by the one of villager that they hardly use as the selling of vegetable, they normally use for village gathering.

Village is strongly access to information, where radio and television fed them important information. It was observed that every household has radio and mobile phone. Even though the number of owning television is very few.

Sources of energy is easily available, the electricity well connected and where people can afford. Villagers use electricity for cooking and lighting.

4.2.5 Financial Capital

The people of Samdingkha village they do not have any formal saving of money. Most of the villagers are farmer, which is just enough to sustain them self to next harvest. They get inflow of money by selling the surplus rice and by selling the cash crop in the market. The money they get they have to spend for the children education and for the buying of grocery item. Though the education is free but for higher studies money is being spend more by their children.

They are given small loan for buying of farm machinery by the government.

4.3 Observation after resources mapping

After the resources mapping and among all the resources, community need to have roof over the evacuation site, as its very vulnerable if the GLOF disaster comes in the monsoon season, where by community are not able to store their assets. And it can be use to store community food items and held mass gathering too, not only that community can use as children play school.

Another important things is that community they are aware of danger zone area, but still they prefer to build house and establish the commercial area is just on the bank on the river, the government should provide all the basic necessity at up hill which are same as near the river area. As GLOF is natural hazards is a natural hazard that can't be eradicated completely.

4.4 Vulnerability assessment

Vulnerability is never same for everybody of different society and background to different given situation as because their level of vulnerability level might be different, As poorest society have fewer and less capacity and opportunity to face the hazards, but when any disaster events strike the general scenario is more or less same to all and everybody is vulnerable. Not being poor does not necessarily mean not being vulnerable, and vise versa.

Samdingkha village and its communities are one of most vulnerable area of GLOF disaster. This very village had experience three times hit by the GLOF event and causes huge loss to its livelihood. During my field visit in the Samdingkha Village I have asses the vulnerability of the community, but also their assets and livelihood pattern.

4.4.1 Type of Vulnerability

Vulnerability is the conditions determined by physical, social, economic and environmental factors or processes. Factors that increase the susceptibility of the community to impact of hazards; is a set of prevailing that consequential conditions which adversely affect people's ability to prevent, mitigate, prepare for and respond to hazards. And also the five resources in any given situation under any events that take place is considered vulnerable. The loss and damage will be asses on the context or based on the resources that are directly under thereat or in other term vulnerable when disaster take place. To categorization of vulnerability are given below:

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

4.4.1.1 Social resources Vulnerability

Social vulnerability assessments were derived from the demographic and social characteristics such as the household structure, and the community. The local capacity for GLOF risk management was assessed through household income and livelihood support (sources of income, landholding size, and food sufficiency), preparedness plan and practices.

In Samdingkha village the two flooding in 1957 and 1960 then after 24 years, in 1994 flood, as they were not use to this kind of disaster, it created shock for the community in the village. That is because there were no proper guidance and assistance, only after 1994 flooding government have taken step and planning on GLOF Disaster and affected community. Early warning system were newly established, there are tow type of early warning system manual and automatic early warning system. When it come to automatic warning system (serine) people are not fully have faith on it, as few villagers said there are few times false warning. But few says they are now safe as they know when GLOF disaster is striking. There is lack of faith and trust in warning system, for that people should given chance and educated on the early warning system.

When it comes to income it is fixed, but with change of times when all the commodities and living standard are being improved, it had been difficult to cope up with. As their main sources of income are from agriculture where there is less people to make it in use. Most of member of family they go to city for less hard work. People need to give awareness about the important of agriculture.

Government have conducted many awareness on GLOF Disaster, and even community where given the opportunity to practice mock drill on evacuation, still some of the people are confused what they are doing.

As most of important installation like forest office and all the shops of Samdingkha village is geographical located in Red Zone area, there is no chance if saving the house and others assets if GLOF strike. It should be relocated as soon as possible because its never know when the flooding will strike.

4.4.1.2 Human resources vulnerability

Disaster statistics shows that the frequency and intensity of extreme natural events have been increased in recent years (UNDP 2004). Due to increase in population in the village there are there are so many settlement coming up near the red zone i.e. near the river area. Therefore the vulnerability of people are increased due to unsafe construction practices.

4.4.1.3 Economic resources vulnerability

The economic element exposed to GLOF's includes lives, property, infrastructure, and livelihood support system. As most about majority of agriculture land are in Red zone area, houses and livestock are directly threat to the flooding. There by huge household assets are being lost. The main road, which connects the village, runs just on the bank of the river so in times of GLOF events road is highly vulnerable, where by even to give the medical aid and any necessary help will be cut off.

4.4.1.4 Natural resources vulnerability

1994 GLOF event was the most devastating in this village and mostly affected the land, crops and destroys houses. Due to over grazing and deforestation, that reduces the impact in times of flood.

4.4.1.5 Physical resources vulnerability

The most physical vulnerability is location of the commercial area just on the bank of river. The bridge with connect the two village also located near the commercial area. And also most of the important installations like forest office, and shops and community vegetable market.

4.4.2 Observation after vulnerable assessment

- There are many houses and important installment residing near river which makes area GLOF prone area, making them inability to move from red zone area to their homes being "permanent structures", and few villagers they had" no where to go".

4.5 Effectiveness of early warning system

When interviewed with the villagers few responded, that they felt GLOF event could occur during heavy rainfall and few villagers believed it could happen immediately after an earthquake or due to rapid melting of snow. But interestingly, that few villagers believed the traditional belief of GLOF events occurring due to the "wrath of the deities protecting the lake".

Villager have got almost have faith in EWS, believed that they will get the information through EWS that was being placed by the project. They even did practices few times mock drill on EWS. But there are few of them they are still unsure weather they will get the information or early warning as EWS had been newly installed and not been used or function during live GLOF disaster. But communities are aware about the early warning system.

4.6 Observation on Indigenous Knowledge in CBDM

In Samdingkha village there are series of Community Based Natural resources Management workshop are conducted with technical assistance from National Soil Service Center (NSSC), these Vulnerable communities were given concepts on climate change and oriented on environmental environment such as forestation, mountain eco-system, land-use management and water/watershed management measures as they constitute an important element in climate adaptation and disaster risk reduction strategies.

Pho Chu, the perennial glacial fed river originating from the moraines brings every year huge amount of boulders, moraines, sand and stones. The sheer force of the floodwater every monsoon drastically changes the course of the river resulting in erosion of the riverbank and flooding of farmland with sand and boulders. Accordingly, communities have invented bamboo plantation, which would not only work as line of defense against the force of the GLOF and flash flood hazards but also supplement the source of income of local community. Strong roots/soil holding capacity made it the ultimate choice. At the beginning, about 250 bamboo saplings were planted in a kilometer long stretch with the active involvement of the community.

About 250 enthusiastic school students of Samdingkha planted about 1500 bamboos and willow tree sapling in the GLOF and flash flood prone river bank in Samdingkha. The plantation would not only protect the fast degrading forest area but also work as a tangible flood mitigation measure.

The Advantages of such intervention are:

- It reduces the impact, in an event of flood
- It is cheaper, faster and easier to do
- Once bamboo are fully grown, it can be harvested for economic benefits
- Bamboo has high carbon intake. Hence it not only reduces the flooding impact but it is also a mitigation measure.

4.7 Assessment of Disaster Management Model: EXPAND – CONTRACT MODEL

In this model, disaster management is seen as a continuous process. There is series of activities that run parallel to each other rather than as a sequence. An emphasis on each of the activities changes with regards to the onset of the disaster.

4.7.1 Prevention and Mitigation Strand

Prevention: Activities to provide outright avoidance of the adverse impact of hazards and means to minimize related environmental, technological and biological disasters (UN/ISDR).

Mitigation: Structural or non-structural measure-taken undertaken to limit the adverse impact of natural hazards, environment degradation and technology hazards (UN/ISDR)

In Samdingkha village though people are vulnerable to GLOF hazards, but communities are aware of prevention and mitigation with their own local knowledge and help form the government and NGOs. They use indigenous knowledge in the preparation stage; for example, they notice the change of behavior of domestic animal and birds. Kinds of madness arise in the behavior of these birds and animals and they become restless. More over community in their own initiative they have build stone lining in lieu of gabion wall/concrete flood protection wall at breach points along the riverbank. Bamboo plantations, which not only reduce the force of flooding and prevent riverbank erosion but also it, mitigate better carbon sequestering capacity. In term of level of awareness of their role and responsibilities, addressing disaster risk in the CBDRM process, the communities of Samdingkha village are in good shape observed during my visit in the village.

4.6.2 Preparedness Strand

Preparedness: Activities and measure taken in advance to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threaten location (UN/ISDR).

Regarding the preparedness measure adopted by Dzongkhag and community are working the plan for relocation of vulnerable houses and formation of various committees as part of preparedness. Some of the community has cited prevention of unsafe construction practices, construction of retention wall and reservoir tanks and plantation of trees and bamboos as risk reduction and preparedness measures.

Measures to enhance preparedness in case of GLOF are awareness and trainings, which with help of government and NGOs they are fully involved with the villagers. Prevent construction of houses in red zone area and relocation of vulnerable houses. Communication and information sharing, this include with the communities living up stream and down stream, which will benefit both in preparedness of GLOF hazards.

4.6.3 Relief and Response Strand

Relief/Response: The provision of assistances or intervention during or immediately after disaster or met the life preservation and basic substance needs of people affected. It can be of an immediate, short-term, or protected duration (UN/ISDR).

Communication and information sharing play very vital role, as in Samdingkha village they are fully aware and connected with good network. An establishment of early warning system in different point and also ingenious early warning system provide vulnerable communities response to hazards in case of lake outburst. In Samdingkha village it had been already earmarked the evacuation site, once they hear the early earning from any means, they immediately share the information with others and start moving to the evacuation site or to a safer place.

For the relief communities have Basic health unit, which provide medical aid in times of disasters. For emergence relief and response community are in good linked with government with NGOs. Communities have been given basic search and recuse training and during the peace times community practices mock drill in evacuation site.

4.6.4 Recovery and Rehabilitation Strand

Recovery: Decision and action taken after a disaster with view to restoring or improving the pre-disaster living conditions of the stricken community, while encouraging and facilitating necessary adjustments to reduce disaster risk. Recovery affords an opportunity to develop and apply disaster risk reduction measure (UN/ISDR).

Community have been actively involved in recovery and rehabilitation activities, afforestation which during the disaster it lower the intensity of hazards and gives income side by side too. They have good number of evacuation site and the village is clearly marked with hazards zonation with evacuation route. They have even improved the style of building construction to minimize the loss in case of

GLOF hazards. Stone lining in some of vulnerable point which community maintain at all time.

During my visit in Samdingkha village I had notice that communities they take pride in protecting the rehabilitation strand, they met and discuses to minimizes losses from GLOF hazards. Government and NGOs affiliated with vulnerable communities are strongly linked in times of disasters.

4.8 Experiences with GLOF Disaster

4.8.1 Kencho 70 years/ male, Farmer

Figure 4.6: Mr. Kencho as on 18th Oct. 2012

It was 53 years ago when I was a 17-year-old boy I have witness GLOF for the 1st time in my life. It was in 1957 when my father and village men had gone for road construction work between Phuntsholing and Thimphu. During that time i was getting ready to go for rice grinding to Punakha, as there is no rice mill then in our village. At around 4 am in morning I heard very loud noise like thundering, people shouting, cows, horses and running uphill. Suddenly my mother pushed me and told me run. I ran up hill and I was shocked and saw huge waves of river flowing and covering all area near the river valley.

As of now, I could still remember how Ap Domchu and his 4 family member how flooding have washed away in this tragic incident. They lost their lives, house, cattle and all their belongings. We could not help him we were helpless. But to those people whose house were destroyed and filled by sand, all our neighboring up hill had help each other and rebuilding homes and bring back to normal life.

4.7.2 Lhaden 60 years/female, Shop Owner

Figure 4.7: Mrs. Lhaden as on 18th Oct. 2012

It was around 6am 7th Oct. 1994 when dreadful flood had snatched away all my general shop items worth of 2 lakhs ngultrums. I was 42 years old with 2 month pregnant with my youngest daughter. At the time of flooding i was sleeping my brother woke me up and directly took me to up hill. Later my brother told me that, he first thought that it was vehicles noises. As in our village, that time hospital was under construction and many vehicles ply with construction material. But he said, the noise is not of vehicle its of giant wave of river moving with very high speed.

After the post flooding, bridge was washed away and my shop was completely destroyed and fully filled with sand. Everything was lost and we stay in temporary shelter, till with support from the government and neighbors at up hill I could rebuild my house and restart my normal life. With my relatives financial help I could restart my business and till date I am running the shop.

4.7.3 Namgay Tshering 51 years/male, Mechanic

Figure 4.8: Mr. Namgay Tshering as on 18th Oct. 2012

During my filed visit in Samdingkha Village I met Mr. Namgay Tshering repairing water pump in one of villager house. I asked, Do you know about GLOF and if yes, please share some of your experience he said, sure I am mechanic and help my village fellow by repairing farming machineries with minimum rate and during the off day, I work in my own field. I have been just reached after my mechanic training from 1987 to 1994 at Paro when I witness dreadful flood in 7th Oct. 1994. The flood started early in the morning with pure water and wooden debris followed before reaching its peak at 9am. At that time main bridge was washed away which linked two villages. And also eroded the roads and filled with sand whole over the field and houses.

CHAPTER 5
CONCLUSION AND RECOMENDATIONS

5.1 Conclusion

This present study is place-based community Based GLOF disaster Management. It has been developed by using theoretical framework and model and presented the finding by field visit. This research provides how Community Based Disaster Management can adjust with Climate Change and GLOF hazards. My research has adopted a DFID sustainable livelihood framework and Disaster Management model to study the problem of the GLOF hazard. This study attempts to fill the gap exists between the Government/NGOs, GLOF hazard and Community by CBDM. Samdingkha village has been assessed by Sustainable Livelihood framework and five-core capital of livelihood pentagon, which provide theoretical study of Community Based GLOF Disaster Management. Following the objective of the study, some of the findings, which could be concluded, are stated below:

- The Government of Bhutan and NGOs has been working towards raising awareness through development of materials and dissemination of information to communities. However, for the better-cost effectiveness and sustainability of CBDM, there should be definite awareness message before, during and after disaster, and implemented and ongoing activities related with GLOF hazards to the target group.
- In term of early warning system, there are two type Manual early warning and automatic early warning system, which very good example of how communities can be informed within the larger early warning system. Even with the set up of the automatic system, the manual early warning should be continued, which can be contingency plan.
- Though it was very helpful to the communities that, the government has identified evacuation site and hazards zonation of the village. There were frequent mock drill conducted and practices in case of GLOF disaster. But what will happen if GLOF disaster event occurs during the monsoon times. There are no roofs to keep their properties.

- Thought majority of the community are aware of causes of GLOF disasters, but there are few in general are not aware of disasters and believe that the disasters are spell of god and local deity.
- Bhutan lies under a highly seismic risk zone, and Samdingkha village especially lies among one of the most vulnerable area need to educate the community even on earthquake also, where its after effect can led to outburst of glacier lakes.

5.2 Recommendations for Further Studies

Based on the study and discussion made above, the study recommendations of livelihoods of Community living in Samdingkha village are as follow:

- The government participation on awareness and capacity building is high in all levels. But, still there should be sensitization/awareness campaign on the hazard zonation and discouraging construction in the red zone area. There is need of dedicated disaster management in the district level. In community level emergency relief first responder during disaster, training should be given with paramount important on search and rescue and first aid.
- Samdingkha village had experience GLOF disaster for 3 times in 1957, 1960 and 1994. For 1957 and 1960 there were no records/documents available. There should be proper maintains of documents for further studies like how the communities have suffered, losses, mobilized themselves and responded in the situation and on existence of any indigenous skills and knowledge that are present and how to utilized it.
- The Disaster related organization have been stressing important of red zone area its risk is construction are being build. But on other hand Communities living in risk prone area are left confused state that government is building in red zone such as, Hydropower project, huge institution, and even airstrip. The government need to clearly to communities why and how? And educated the communities.

- There is need to build trust on early warning system installed by government as most of the communities felt that they were better prepared than before to face disaster, especially in case of a GLOF event.
- The government had demarcated and hand over the evacuations site to the communities. But, the evacuation sites are all in open area no roofs above. In case of GLOF disaster occurs during the peak monsoon times. There will be threat to the food security because there lack of storage.

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Appendix A

Checklist

A. General information

Household No.: ________________ Respondents Name: ________________________

Village : ___________________________________Gewog: ______________________

Gender: M/F____ Dzongkhag: ____

Date: ________________

- How long have you been living in this village?
- Is this village your ancestral village of you parents/grandparents? (If NO from where did you migrate)
- How many of you are living in your house?
- What is the main source of livelihood?
- How many of you are working in filed?
- If farmer:
  a. What is size the land you possess?
  b. What crop you all grow mostly for living?
  c. Do you all grow cash crop? (YES/NO)
  d. If yes –Which cash crop and where do you sell?
  e. Do you own cattle (YES/NO)
  f. If yes – how many cattle/sheep/yaks do you have?
  g. What is your monthly income?
- If shop keeper:
  h. What type of shop you own?
  i. How long have you been doing business?
  j. Which item sells the most? Why?
  k. From where do you get your stock?
  l. What is your monthly income?
- Why do you choose to live in the river valley, why not uphill?
- What do you think is the advantage and disadvantage of living in the river valley?

B. Social mapping

Name of the village: ____

Number of people attended: ____________________

Number of people Interviewed: ___________Date: ___________________

1	How old is this village?
2	What is main the occupation of the people?
3	What are the main resources in this village?
4	What are the natural resources of this village?
5	How many schools are there in the village?
6	What is the cultural practice in the village?
7	How many monasteries are there in this village?
8	How are the drinking water facilities in the village?
9	How is the condition of drinking water and sanitation?
10	How many shops are there in this village?
11	Is there any health care center in this village?
12	How is the health condition of the people?
13	Is there irrigation canal?
14	How is the transportation?
15	How is the road condition?
16	Is there any bus service? When? How many times in a week?
17	Is there any disaster management center?
18	Is there any government office located in your village? (YES? NO)
19	IF YES- what are the offices and its purpose?
20	Is there any disaster management center located?
21	Is there any disaster early warning system located in your village?
22	How many rivers are there?
23	How many bridges?

C. Vulnerability Issue

Name of the Village: ____

Number of Interviewed people: _______Date: _____________________

SL.No.	Vulnerability issue	Zone	Statistics (High/Medium/Low)
1	House		
2	Shops		
3	School		
4	Crops		
5	Domestic animals		
6	Health center		
7	Lack of land		
8	Water sanitation		
9	Irrigation channel		
10	Lack of electricity		
11	Lack of food		
12	Pest		
13	Insufficient income		
14	Bank erosion		
15	Social attitude		
16	Drainage congestion		
17	Epidemic		
18	Corruption in local administration		
19	Decline of income		
20	Loss of embankment		
21	Siltation		
22	Monastery		
23	Bridges /Culvert		

D. History of GLOF Disaster: Hazard and Risk Perception

Name: ____Age______________

Gender: M/F____________ Occupation: ________________________________

Village: _____________________________________Date: _________________

1. What is GLOF?
2. When did Pho Chu flood occur?
3. What times of year do flood come?
4. Does it flood during the monsoon season or in dry season?
5. Have you experienced flood? (YES/NO)
    a. If YES: how many times you have seen flood? In which year?
    b. IF NO: have you heard about flooding from older people?
6. Which year was the most challenging in dealing with flooding and why?
7. What do you think cause of the flood?
8. Do you know the source of Pho Chu?
9. Are you aware of Glacier Lake?
10. Do you know the Thorthormi tsho, Luggue tsho and Rapstreng tsho? (YES/NO)
    a. IF YES: When and who told you?
    b. IF NO: Did not you hear from people talking being mention by elder people?
11. Have you been to sources of Pho Chu?
12. Please explain briefly about the glacier lake like location, size, shape and distance from your place?
13. Explain briefly about the 7th Oct. 1994 GLOF event experience?
14. Were there was early warning during 1994 flood?
15. How you would feel if you experience GLOF again and would you be afraid?
16. What will be the effect of devastating GLOF in your village?

E. History of GLOF Disaster: Living with GLOF

Name: ____Age______________

Gender: M/F____________ Occupation: ________________________________

Village: ______________________________________Date: _________________

1. Do you all get support from Government and NGO for emergency relief and rehabilitation?
2. Do you think support is sufficient for you?
3. Are you aware of early warning system (Siren) in your village? Is it working?
4. How much faith do you have in early warning system?
5. Do you have any idea about the ongoing project at Thorthormi tsho?
6. Will the project be helpful?
7. Do you think community has any role to mitigate the impact of GLOF?
8. If you are warned about the impending GLOF and told to evacuate, where would you go, and what would be your role?
9. Do you have any preparedness to face GLOF disaster?
10. How your community can become resilient to disaster?