HAZARD AND RISK: PERCEPTION OF GLACIAL LAKE OUTBURST FLOODING FROM TSHO ROLPA LAKE, NEPAL

By

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A THESIS

Submitted in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE IN ENVIRONMENTAL POLICY

MICHIGAN TECHNOLOGICAL UNIVERSITY

2008

This thesis, "Hazard and Risk: Perception of Glacial Lake Outburst Flooding from Tsho Rolpa Lake, Nepal," is hereby approved in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN ENVIRONMENTAL POLICY.

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Acknowledgements

There are a number of people I wish to thank for their assistance and support throughout my field research and thesis writing. My sincere thanks go to my advisor Bradley Baltensperger for his guidance and input into my research efforts from the beginning. Moreover, he provided me the fund necessary to go to the field. Otherwise, this research was absolutely impossible. I would also like to thank Hugh Gorman and William Rose, the members of my thesis committee, for their valuable feedback and recommendations.

I am grateful to my teachers in the Environmental Policy (EP) program, particularly, Barry Solomon and Kathy Halverson, from whom I learned a lot of stuff useful for this research. Similarly, thank you very much my friends in the EP program – Nelson, Stacey, Nick, Andrew, Genevieve, and Susanne – especially for the fun and encouraging conversations I had with you guys ! My special thanks are due to Kelley Durst who helped me get GIS data, and Bharat Pokharel who helped me format the thesis and presentation slides.

Last but not least, my indebtedness goes to my wife Sunila and son Sarik for their constant cooperation and inspiration. I heartily appreciate that Sunila assisted me in interviewing some of the women respondents for the research. Finally, I would like to dedicate this thesis to my parents who instilled in me that patience is the best remedy of all difficult moments in life.

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Abstract

People's perception of risk of a particular hazard positively influences the adoption of effective mitigation strategies and responses. Glacial lake outburst flooding (GLOF) has emerged as a major natural hazard in the Nepal Himalayas in recent decades. The present study explores the risk perception of people living downstream from Tsho Rolpa Glacial Lake of Nepal. It is important to understand if downstream populations are aware of the probability of a Tsho Rolpa outburst flood and perceive the risk of being flooded, at a time when experts involved in hazard assessment claim that the lake still poses a high risk, despite some mitigation works. This study reveals that the local people have a low risk perception of the Tsho Rolpa GLOF. A majority of them demonstrated dissonant risk perception. No adjustments have been adopted by the people at individual level. The low risk perception on the part of the riverine people is chiefly attributed to the cry-wolf effect of the 1997 evacuation that followed the unfounded expert prediction of a Tsho Rolpa outburst. The preliminary remediation works kept in place have created a false sense of security among the people. It seems they are living fearlessly in the hazard zone. At some places, people have moved even closer to the river channel to settle. Paradoxically, the numbing effect of the partial mitigation efforts has increased the vulnerability of the communities to a probable outburst flood.

Chapter 1: Introduction

In the Himalayas, deglaciation, the retreat and thinning of glaciers, has accelerated since the 1960s (Ageta *et. al.*, 2001). As a result, glacial lakes are increasing in number and volume, creating a risk of potential glacial lake outburst floods (GLOF). Although GLOF events have been common phenomena in the glaciated parts of the Himalayas since time immemorial, their occurrence has increased during the last few decades. In Nepal, one outburst flood on average has occurred every three years since the 1960s (Kattelmann, 2003). Such events often result in huge damage to downstream natural resources and physical infrastructure. They can cause great loss of livestock and human lives, apart from resulting in long-term environmental degradation.Towns and villages in steep, narrow valleys downstream from such glacial lakes are at danger.

Basically, there are two common types of glacial lakes worldwide – moraine-dammed and ice-dammed. In the Himalayas, moraine-dammed are the dominant type (Richardson and Reynolds, 2000). Such glacial lakes are formed when piles of rock debris (moraines) impound water behind them as the glaciers melt and retreat from their maximum extent. These moraine-walled lakes are structurally weak and unstable, so there is significant danger of catastrophic flooding due to slope failure and slumping (Ives, 1986).

Assessment and evaluation of GLOF as a natural hazard posing risk to the populations and infrastructures downstream from the glacial lakes is a recent activity in Nepal. Attention of the government agencies and scientific community was drawn mainly following the occurrence of Dig Tsho Glacial Lake Outburst Flood in 1985. The catastrophic flood, which washed away acres of arable land, trekking trails, a hydropower plant, and a couple of suspension bridges, in addition to killing five persons, (Ives, 1986; Vuichard and Zimmermann, 1987) stimulated glacial hazard research, chiefly on the floods from moraine-dammed lakes . Almost all the research works carried out on GLOF in the Himalayas concentrate on geo-physical and technical aspects of the hazard, and are undertaken chiefly by engineers, geologists, climatologists, or persons with technical expertise. Some of these researchers have concentrated on examining and measuring the horizontal expansion of glacial lakes to determine the potential outburst (Sakai *et. al.*, 2000), while others have investigated bathymetric changes of the glacial lakes (Benn *et. al.*, 2001). Similarly, researchers such as Ives (1986) and Damen (1992) have focused their studies on describing the impacts caused by and lessons learned from past GLOF disasters. Other researchers have come up with comprehensive inventories of glaciers and glacial lakes, identifying the potential for outburst (Mool *et. al.*, 2001). Such studies were done through different procedures such as remote sensing and field investigations, often using photographs, maps, and satellite images.

On the other hand, there is no research work of significance that deals with the social aspects and vulnerability of people living downstream from the potentially dangerous lakes. Studies are rare on topics such as people's perception of GLOF hazard, community-based mitigation, emergency preparedness, disaster responses, and local people's resilience. Perception studies do not exist in the literature of GLOF hazard in the Himalayas. The present research seeks to fill this void by exploring the risk perceptions of people living in the hazard zone downstream from one of the potentially dangerous glacial lakes in Nepal.

In hazard literature, risk perception is usually described as the potential victims' comprehension and assessment of the probability of environmental extremes. It is the people's cognition and belief in the gravity of threat possessed by an extreme natural event (Mileti, 1980). Often, the impacts and perceptions of hazards upon the local population are determined through field surveys, workshops, focus groups, and individual interviews. As individual perception of natural hazard is an influencing factor in effective mitigation and response (Tobin and Montz, 1997), the information obtained this way might be useful in developing socially acceptable plans for potential disaster management in the region. Such a structured risk management approach includes the systematic and objective assessment of risk, specific understanding of uncertainty, and proposed strategies for the mitigation, preparedness, and response to the potential disaster.

Unlike other hazard events such as larger earthquakes, tsunamis, and major volcanic eruptions, GLOF events are not typically the cause of a huge number of fatalities. The largest major GLOF catastrophes reported so far have killed some 20,000 people in Peru (Lliboutry *et. al.*, 1977), 23 in Bhutan (Richardson and Reynolds, 2000), and 5 in Nepal (Vuichard and Zimmermann, 1987). The damage these outburst floods caused to property and physical infrastructures in downstream communities was enormous, and long-lasting. In order to reduce the risk and losses caused by probable GLOFs, it is pertinent to address questions such as: How does the occurrence of GLOF events affect the people living in downstream valleys? How do they perceive the GLOF risk? Why do they continue living in such a risky environment? How are they prepared in case such an event happens? What sort of assistance do they need from government and development agencies to reduce the risk?

To answer these questions, I chose to study the riparian communities located in the valley downstream from Tsho Rolpa, a potentially dangerous glacier lake of Nepal. My research focuses on determining local knowledge about GLOF risks. By conducting personal interviews with the local people, I collected information about risk perception of people and the potential adjustments to GLOF risk. Besides, the study aimed at identifying how local communities could contribute to policy solutions. While focusing on understanding their shared perspectives on the causes and impacts of GLOF, I made observations of the factors that have enhanced people's social and physical vulnerability to an impending outburst flood event.

Based on the results of my field study, I offer some policy and behavioral recommendations in Chapter Five, targeted at government officials, donor agencies, NGO workers, local politicians and the riverine people. Before reaching to the conclusions, I will dwell upon the background, methodology, results, discussion of the results, and significance of the study. Chapter Two presents background information on natural hazards, risk perception, and the GLOF hazard. Chapter Three describes what methods and instruments of data collection I used to study the communities. Accompanied with corresponding discussions, the results of the study are presented in Chapter Four. Significance of the study is highlighted while exploring some implications in Chapter Five.

Chapter 2: Background

2.1 Natural Hazards and Disasters

Nature has been both the provider of resources and source of hazards to humankind since its existence. Whatever in the environment is useful to humankind becomes a resource, while anything that poses a threat becomes a hazard. As humans constantly interact with the environment they are living in, they often come into contact with hazardous forces. Although they endeavor to thwart these hazards using different social and technical mechanisms, they are rarely able to triumph over. As a result of population expansion, land pressures, and increased wealth, the number of disasters, global death tolls, and property losses are on the rise.

According to Munich Reinsurance Company (2006, cited in Abbott [2007]), 274 large-scale natural disasters occurred during the period from 1950 through 2005, showing an upward trend. In the 1950s, 2 great disasters (at least 1,000 deaths) occurred annually, while the average annual number of occurrences of such disastrous events went up to 5 by 2005. Swiss Re (2006, cited in Abbott [2007]) shows that the average annual disaster toll rose from about 12,000 in 1980 to 100,000 in 2005. Of the 40 most disastrous events that occurred in the 36-year period from 1970 to 2005, 38 were due to naturally triggered-events, and 26 occurred in Asia alone. Likewise, economic losses increased 6.6 fold during the 1950-2005 period while insured losses rose 24.8 fold (Abbott, 2007). More than 75 percent of economic losses occurred in developed nations like the USA and Japan. Smith aptly says, “in disasters, the poor lose their lives while the rich lose their money (2001: p 34).”

These burgeoning losses are attributed to interactions among earth’s physical systems, demographic and political characteristics of societies, and their built environments (Mileti, 1999). Looking at this trend and the world's population growth rate, more fatal disasters are likely to occur in future. The Indian Ocean Tsunami of 2004, Hurricane Katrina of 2005, Pakistan Earthquake of 2005, Myanmar Cyclone of 2008, and China Earthquake of 2008 are some of the recent large-scale disasters. Because of the substantial losses and human suffering they cause, these events often draw national and international attention. Global recognition of disaster events has increased. As a result, hazards and disasters have become topics of worldwide discussion in recent years. Yet, there prevails confusion and inconsistency in the usage of these terms, which need to be clarified before any discussion of the topics.

2.1.1 Extreme Events in Nature, Hazards, and Disasters

In lay parlance and popular media, the terms 'Extreme Events,' 'Natural Hazards' and '(Natural) Disasters' are often used interchangeably to mean more or less the same thing: occurrences in the environment that are overwhelmingly harmful to humans and their property. Yet, the terms bear distinct meanings when they are discussed in the natural hazards literature.

2.1.1.1 Extreme Natural Events

The planet Earth is characterized by dynamic geo-physical processes which constantly undergo fluctuations. Any occurrence or state of such phenomena in time may be termed as a natural event. When such an event reaches the outer limit, it becomes an 'extreme' (Smith, 2001). Rain, for example, comprises an event system in nature and it becomes an extreme the moment it causes flooding. Burton *et al.* (1993) define the natural events system as "the array of wind, water, and earth processes, which functions largely independently of human activities and is an object of scientific inquiry in its own right by meteorologists, hydrologists, and geologists." They give an example of lightning as an extreme event which may be a resource and a hazard at the same time.

2.1.1.2 Natural Hazards

In the ordinary sense, hazard is anything that causes fear of loss or potential harm to humans and their possessions. Extreme events that pose threats or affect humans physically, psychologically, socially or economically are known as natural hazards. Holding the human-ecological perspective, Burton and Kates (1964) defined natural hazards as “those elements in the physical environment, harmful to man and caused by forces extraneous to him.” This definition points out that only those natural events that are harmful to humans are hazards. It equally emphasizes the fact that the trigger is ‘natural’ not social. After a few years Kates extended the definition, highlighting the importance of human adjustments in hazard management as:

> ----a threatening state to man, compounded of an expectation of the future occurrence of natural events which impinge on a human use system that is provided through adjustments, with a certain capacity to absorb the events (1971: p. 447).

Burton *et al.* further elaborated the concept that the interaction of natural events systems and social systems creates either resources or hazards. Stressing the role of human system in defining hazard, they wrote, “Natural systems are neither benevolent nor maliciously motivated toward their members: they are neutral, in the sense that they neither prescribe nor set powerful constraints on what can be done with them. It is people who transform the environment into resources and hazards, by using natural features for economic, social, and aesthetic purposes” (Burton *et. al.*, 1993: p. 32). According to these definitions, even a very high-energy catastrophic event, for example a 10-magnitude earthquake in Antarctica, may not be a hazard if it has nothing to do with human systems. Thus, it is safe to say that all extremes in nature are not necessarily hazards.

There are many other researchers who prefer a more inclusive term 'environmental hazards' to incorporate the study of technological hazards too. Thus Smith (2001) defines hazard as a naturally occurring or human-induced agent/situation with a threat of potential damage.

2.1.1.3 Disaster

In a general sense, when an extreme natural event occurs, resulting in a number of casualties and damage to property and infrastructure, it is termed a natural disaster. Smith (2001) defines disaster, pointing out its difference from a hazard: "Unlike hazard and risk, a disaster is an actual happening, rather than a potential threat, and so a disaster may be simply defined as the realization of hazard." An often cited definition of disaster is by Fritz:

> A disaster is an event, concentrated in time and space, in which a society, or a relatively self-sufficient subdivision of a society, undergoes severe danger and incurs such losses to its members and physical appurtenances that the social structure is disrupted and the fulfillment of all or some of the essential functions of the society is prevented (1961: p. 655).

In recent years, disaster researchers have defined disasters as 'social constructs' rather than the physical phenomena that are objective and external to society (Stallings, 1991; Kreps and Drabek, 1996). This social constructionist perspective holds that disasters are produced through the complex function of social systems, and so the characteristics of a disaster can best be understood through socially defined parameters (Tierney *et. al.*, 2001). Wisner *et al.* (2004) go further and, using the ecological-vulnerability perspective, define disaster as the product of socio-political and economic factors existing in the society. O'Keefe *et al.* suggest considering social vulnerability as the central element in disaster management: "The time is ripe for some form of precautionary planning which considers vulnerability of the population as the real cause of disaster – a vulnerability that is induced by socio-economic conditions that can be modified by man, and is not just an act of God. Precautionary planning must commence with the removal of concepts of naturalness from natural disasters" (1976: p. 567).

2.1.2 Trends in Hazard Literature

The variation on the concepts of hazards and disasters in the literature indicates that there are different views and schools of thoughts. Before social scientists took to the formal study of natural hazards and disasters in about the middle of the 20th century, disasters were widely viewed as the acts of god or nature. This view reflected the uncontrollability of disasters and human helplessness before the wrath of nature. Gradually, natural hazards came to be viewed as the products of human-nature interactions. Human causes of disasters and human efforts to mitigate hazards were explored. This led to the development of new trends in the hazards literature.

2.1.2.1 Hazard Research

The hazard research tradition was developed out of the human-ecology school of thought, which germinated at the University of Chicago in the first quarter of the 20th century with the ideas of John Dewey that "humanity exists in a natural world that is innately hazardous and results in human insecurity" (Mileti, 1999: p. 18). Later, geographer Gilbert F. White pioneered the idea that natural hazards are the result of interactions between human use system and natural events system. Followed and accompanied by other geographers including Ian Burton of the University of Toronto and Robert W. Kates of the Clark University, White's ideas about the process of human adjustments to natural hazards became the crux of what is called natural hazard literature, which with some modifications comprises the dominant research paradigm today. This view maintains that human response in coping with natural hazards, which comprises the adoption of various adaptations and adjustments, has undergone three major techno-social patterns or stages: folk or preindustrial, modern or industrial and comprehensive or postindustrial (Kates, 1971; White, 1973). Major adjustment choices studied by the practitioners of this school are summarized in Figure 2-1.

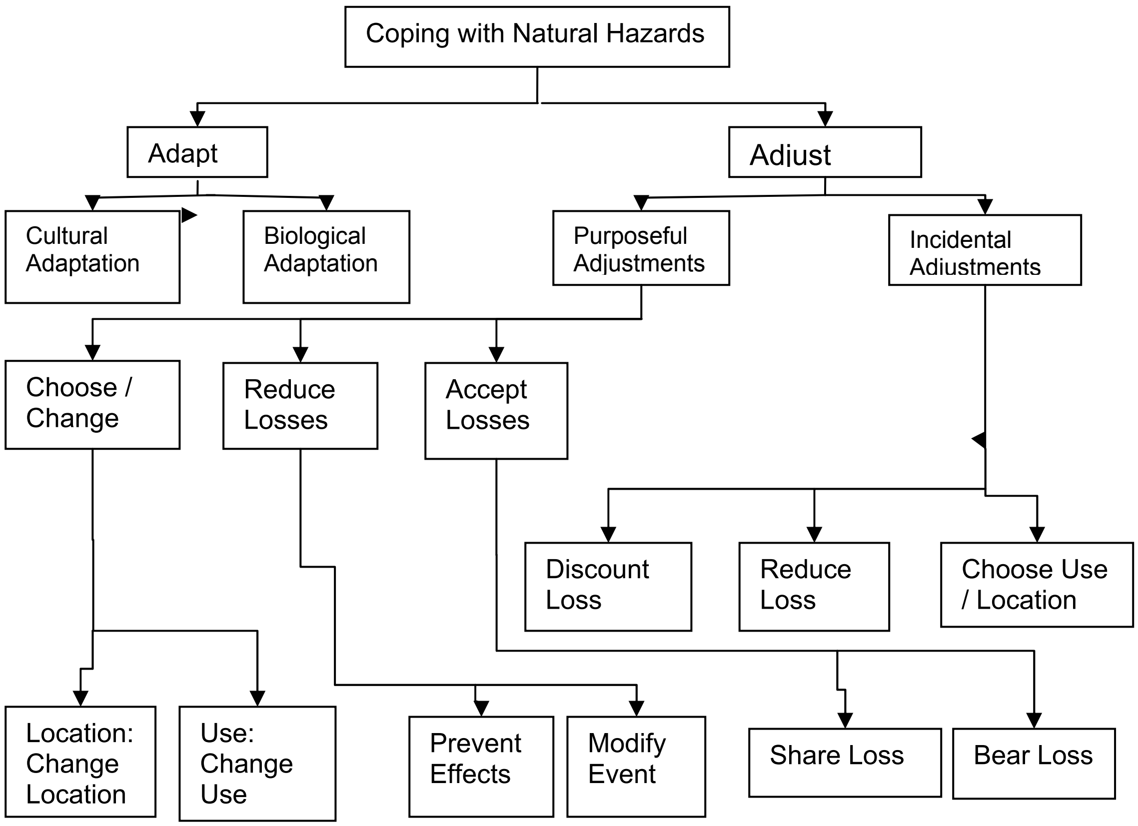

Figure 2-1. A choice tree of adjustments. (adapted from Burton *et. al.* (1993)

Empirical studies carried out on risk perception and hazard adjustments are central to this research tradition. Beginning with floods in the USA, these studies were extended to almost all other hazard types and in other countries. Practiced and developed by geographers and planners, this research tradition focuses on pre-disaster event stages of the hazard cycle (see Figure 2-3). Primarily, works on hazard research concentrate on hazard vulnerability, hazard mitigation, and emergency preparedness as shown in Figure 2-2.

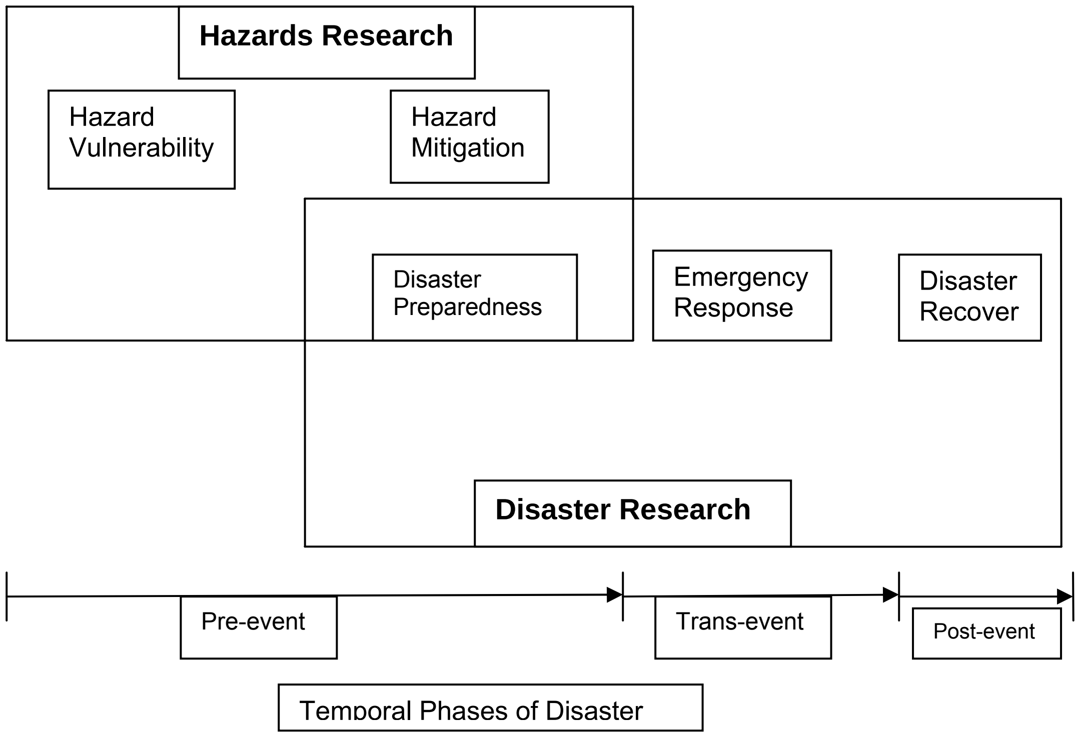

Figure 2-2. Main foci of hazard and disaster research traditions (adapted from NRC, 2006)

2.1.2.2 Disaster Research

Roughly parallel to the hazard research tradition, the disaster research tradition developed independently of the human-ecology heritage (Mileti, 1999). Although preliminary works in this tradition studied technological disasters, later works focused on natural disasters, as well. Developed in the late 1950s and the 1960s chiefly by sociologists with the funding of US military and triggered by concern about the cold war, this tradition focuses on disaster events rather than on mitigation of hazards (Quarantelli, 1988). Studies on disaster research sought to explore public behavior and perceptions immediately before, during, and after the events of mass emergency (Tierney *et. al.*, 2001). As shown in Figure 2-2, major foci of disaster research are on disaster preparedness, emergency response, and recovery (also see Figure 2-3).

2.1.2.3 The Integrated Trend

Around the mid 1970s, both the natural hazards and disaster research studies started extracting theoretical as well as methodological assets from each other's disciplines. As these two traditions were studying more or less the same thing, only with different foci, and had the same goal of reducing losses in future disasters, it was beneficial for both to be integrated. The first assessment of research on natural hazards in the USA, carried out by White and Hass (1975) became the groundbreaking work in bridging the two streams flowing in parallel. The barrier between these two research fields was meaningless as there was no any reason besides disciplinary attachment on the part of both hazard and disaster researchers (White, 1988). This is the approach most planners, policy makers and researchers follow. This interdisciplinary approach to hazard research focuses equally on any component or stage of the hazard cycle shown in Figure 2-3. The whole range of available adjustments shown in Figure 2-1 can be applied in any stage of the hazard cycle.

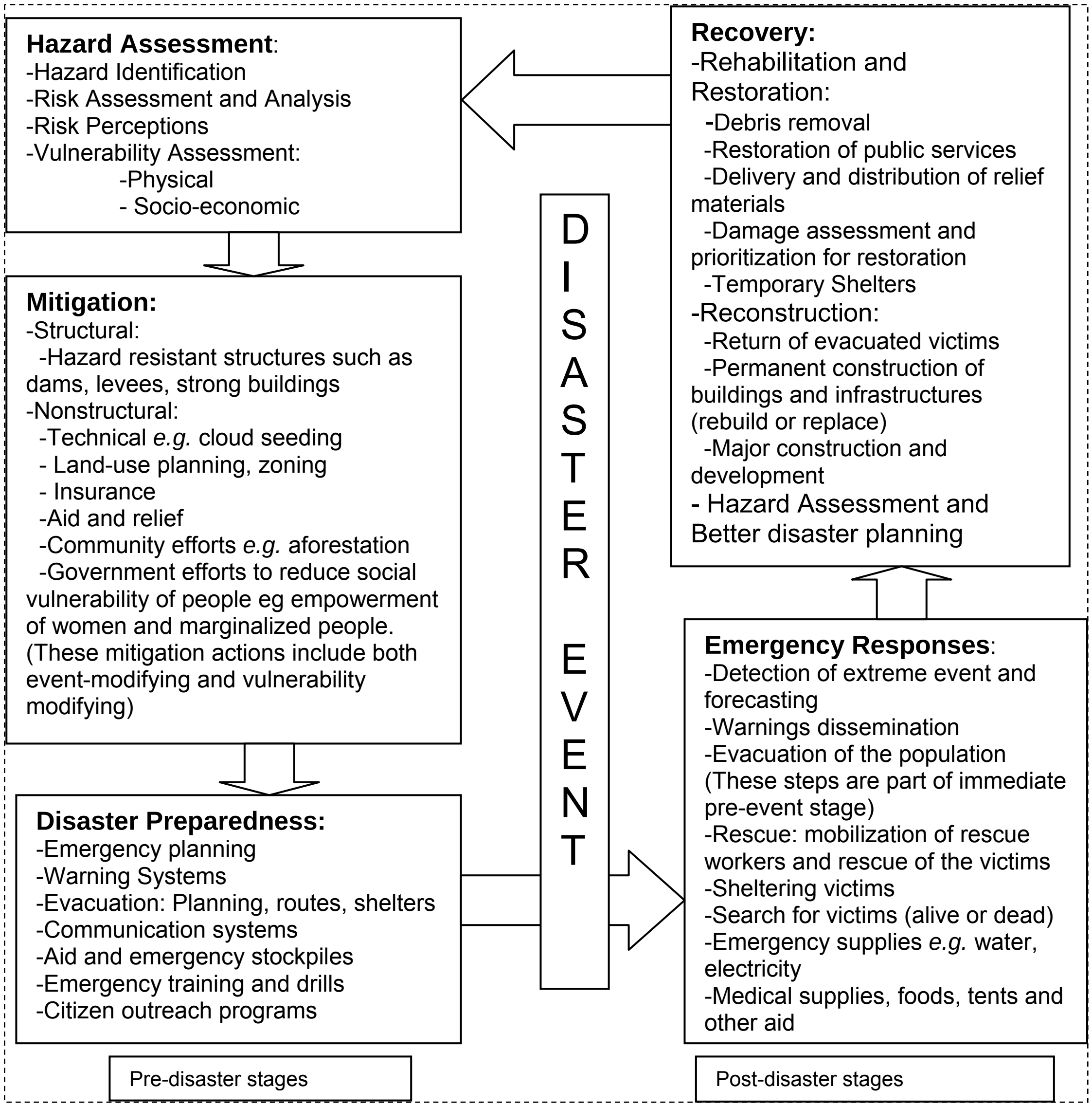

Figure 2-3. Temporal cycle of hazard and disaster (adapted from Mileti 1999).

2.1.3 Hazard Paradigms

The hazard literature includes abundant empirical studies and useful findings. Sometimes it is criticized for lacking sound theoretical frameworks. Yet there are conspicuously different paradigms prevalent in the literature, which have been major sources for the development of policies and management plans adopted by government and private bodies in order to abate losses due to natural disasters. For convenience, the common paradigms are named and explained in the following subsections. These paradigms are not mutually exclusive and have not been defined consistently. For example, it is not uncommon to find in the literature that strategies of sustainable hazard mitigation are advocated by the practitioners of the structuralist perspective.

2.1.3.1 Hazard Adjustments Paradigm

The human-ecology school of thought (see 2.2.2.1) championed the view that adoption of appropriate adjustments could mitigate, if not completely eliminate, the hazard. Summarizing the paradigm, Kates (1971: p. 438) says:

> These varied studies employed all or part of a research paradigm which sought to : 1) assess the extent of human occupance in hazard zones; 2) identify the full range of possible human adjustments to the hazard; 3) study how men perceive and estimate occurrences of the hazard; 4) describe the process of adoption of damage reducing adjustments in their social context; and 5) estimate the optimal set of adjustments in terms of anticipated social consequences (See also Burton *et. al.*, 1993; White, 1973).

Also known as the behavioral paradigm, this approach focuses on the hazard perception of individual managers as well as the community at large. The choice of hazard mitigating adjustments prior to the disaster event, and the role and behavior of individuals at the time of disaster is a function of risk perception (Kates, 1962; Kates, 1963; Mileti, 1980). Thus, the failure to adopt effective adjustments by disaster victims and their inappropriate behavior in times of disasters is attributed to poor risk perception. When faced with a hazard, an individual, a community at large or a government agency makes a choice of one or more adjustments available (Figure 2-1). An individual often makes decision on adjustment choices based on bounded rationality (Burton *et. al.*, 1993). Most of the policies developed at present are based on this paradigm.

2.1.3.2 Structural Paradigm

The proponents of this paradigm hold that hazard events are the product of complex social structuring. Abstract structures of human society instigate and perpetuate a hazardous situation (Mileti, 1999: pp 28). According to structuralists, vulnerability of a society and its constructed environment is the root cause of disaster. “The most vulnerable are typically those with the fewest choices, those whose lives are constrained, for example, by discrimination, political powerlessness, physical disability, lack of education and employment, illness, the absence of legal rights, and other historically grounded practices of domination and marginalization” (Bolin and Stanford, 1998: pp. 9-10). Explaining what this approach holds, Smith says:

> It (structuralist view) asserts that disaster victims are not to blame for their own misfortunes. They do not necessarily lack adequate perception or engage in irrational, hazard-inducing behavior, but – especially in the third World – they have little choice but to locate in unsafe settings where daily survival is the main objective. They lack the time to prepare for emergency action and the resources to recover from disaster. Again, rural over-population and the attendant rise of hazard-prone primate cities are interpreted as a symptom of capitalism, which is seen as a root cause of environmental disaster (2001: p.51).

The structuralists say that social, economic and political factors that create vulnerability of communities should be settled to make people safe from hazards. People’s vulnerability to hazards is generated by root causes such as poverty and limited access to power and resources, and is further increased by dynamic pressures *e.g.* urbanization, unemployment, lack of education, and unsafe conditions such as old houses and lack of preparedness (Wisner *et. al.*, 2004). In the Pressure and Release (PAR) model, they have elaborated how human vulnerability progresses and disaster happens when vulnerable populations are exposed to hazard event (Figure 2-4).

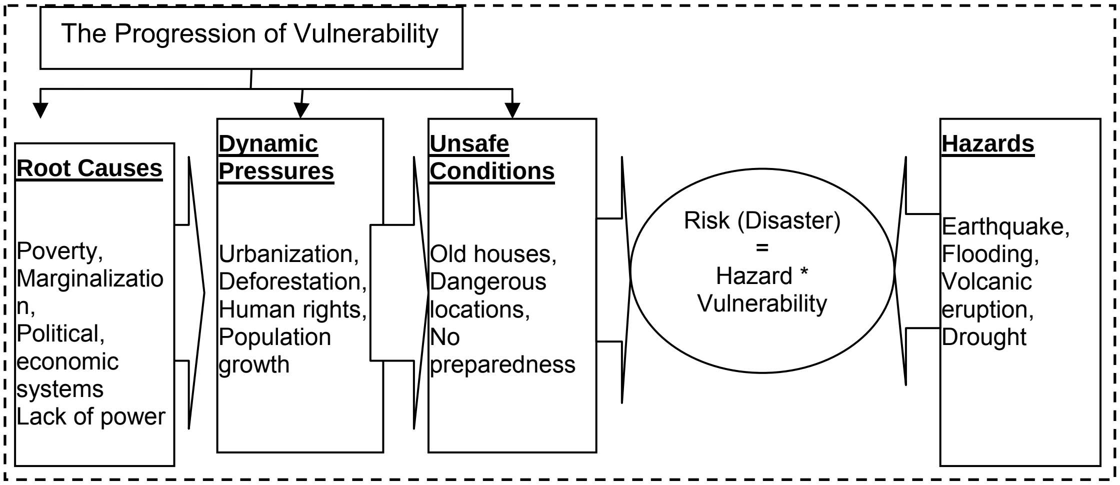

Figure 2-4. The PAR framework: progression of vulnerability (adapted after Wisner *et. al.* (2004)).

2.1.3.3 Sustainable Hazards Mitigation Paradigm

A new framework of thought gaining attention of scholarly debates is sustainable hazard mitigation. This view advocates incorporating the sustainability concept in hazards mitigation as a best way of long-term and reliable hazard management. Sustainable mitigation aims at maintaining the carrying capacity and environmental quality, enhancing people's quality of life, fostering local resiliency, promoting a vibrant economy, maintaining inter and intra-generational equity, and involving local people in decision making (Berke, 1995; Mileti, 1999). Beatley (1998) opined that a sustainable disaster-resistant community is one that maintains safety and achieves development goals at the same time, using different sets of strategies. He offers various suggestions how sustainable disaster management can be achieved. Tierney et al. (2001) use the term 'sustainable hazard and disaster management' that seeks to reduce physical, social and economic vulnerability and facilitate the effective provision of short-term emergency assistance and longer-term recovery aid.

2.1.4 Perception Studies

Perception is “that process by which individuals organize exterior stimuli in order to form some concept of an event or situation” (White, 1973: p. 9). It is the range of judgments, beliefs, and attitudes of individuals living in an at-risk society (Taylor *et. al.*, 1988). The study of perception has been central to both the natural hazard and disaster research traditions. The human-ecology approach places a major focus on the study of hazard perception and perception of adjustments (Kates, 1971). This is important because an individual, a public manager or the community becomes ready for response only when perceiving the threat of hazard. “Choice of adjustments is described in terms of a perception model dealing with the individual manager’s subjective recognition of the hazard, of the range of choice open to him, the availability of technology, the relative economic efficiency of the alternatives, and the likely linkages of his action with other people” (White, 1973: p. 211).

The main focus of disaster research, on the other hand, is to understand individuals’ behavior before, during and after the disaster event, which is inherently tied to their perceptions. The extent to which people show readiness for emergency preparedness and responses to emergency warning is compatible with their perception of the potential disaster event (Mileti *et. al.*, 1975). Followers of this tradition have focused their perception studies on disaster preparedness.

2.1.4.1 Risk

The terms ‘hazard’ and ‘risk’ are often used synonymously to mean the threat posed by potential extreme events. Yet, risk implies more. “It is the actual exposure of something of human value to a hazard and is often regarded as the product of probability and loss. Hazard (or cause) is a potential to humans and their welfare and risk (or consequence) is the probability of a hazard occurring and creating loss” (Smith, 2001: p. 6). Risk means different thing to different people (Slovic, 1987). Risk of a particular hazard markedly varies among the hazard experts and lay population (potential victims). Expert understanding of risk is based on more comprehensive, objective assessment, while lay evaluation results from personal, subjective perception.

Risk determined through a rigorous process widely known as 'risk assessment' is thought to be comparatively more objective and reliable. Assessed risk is viewed to be comprised of the evaluation of the physical characteristics of hazard on question and adjustments adopted. It emphasizes the need to account also for socio-economic and political factors, *i.e.* people's vulnerability (Bolin and Stanford, 1998; Stallings, 1991; Wisner *et. al.*, 2004; Cvetkovich and Earle, 1992). Risk assessment demands for a more comprehensive procedure, which brings together trans-disciplinary experts such as physical scientists, engineers, social science experts, planners, and policy makers. Using both qualitative and quantitative methods, they thoroughly analyze the characteristics of the hazard; determine the probability of occurrence, and likely exposure of population, infrastructure, and property to the event; and investigate physical and social vulnerability of the community.

Following Nott (2006), objective risk can be estimated using the following formulation:

Risk = Hazard Probability * Exposure * Vulnerability * Expected Losses

In the formulation, hazard probability implies the probability of occurrence of an extreme event; vulnerability means the social elements with a potential for losses (vulnerability of both people and their built environment); exposure incorporates the calculation of populations and property likely to be affected; and expected loss implies the economic estimation of lives and property likely to be affected.

Perceived risk, on the other hand, is the individual's subjective realization and/or understanding of the potential threat of the hazard in question. It is the degree of fear and expected loss in terms of deaths, injuries, and damage shaped by their experience and other socio-economic and cultural factors. Unlike the technical concept of risk, perceived risk is the "product of intuitive biases and economic interests, and reflects cultural values more generally" (Kasperson *et. al.*, 1988). This type of risk is the major focus of research on risk perception.

2.1.4.2 Risk Perception

Risk perception basically means the recognition of a potential threat of disaster by individuals or groups. Phrases such as 'hazard perception' and 'perception of hazard risk' are commonly used throughout the literature to mean risk perception. Likewise, there is no consistency in the definition of risk perception. It has been defined as 'the judgment of risk' (Kates and Kasperson, 1983); 'personal estimate of probable fatalities' (Stallen and Tomas, 1988); 'individual's hazard recognition' (Hanson *et. al.*, 1979); expectations of future occurrence (probability) of hazard event and personal vulnerability (Kates, 1971; Tierney *et. al.*, 2001); 'hazard sensitivity in terms of people's awareness' (Burton and Kates, 1964); 'public's understanding of risk' (Hadden, 1991); 'risk assessment made by potential victims' (Greene *et. al.*, 1981); 'citizens' intuitive risk judgment' (Slovic, 1987); and 'subjective assessment of the probability of a specified type of accident' (Sjöberg, 2004).

In the hazards literature, perception studies occupy a central position. In his natural hazard model, Kates (1971) argues that perception of a hazard threshold is the critical variable that frames the decision making of adjustment choices. Thus, hazard perception is the control of the adjustment process. Highlighting the importance of risk perception on adjustments, Mileti (1980) says, "Risk perception of social actors, along with other factors, determines the risk-mitigation adjustments made by social units," as shown in Figure 2-5.

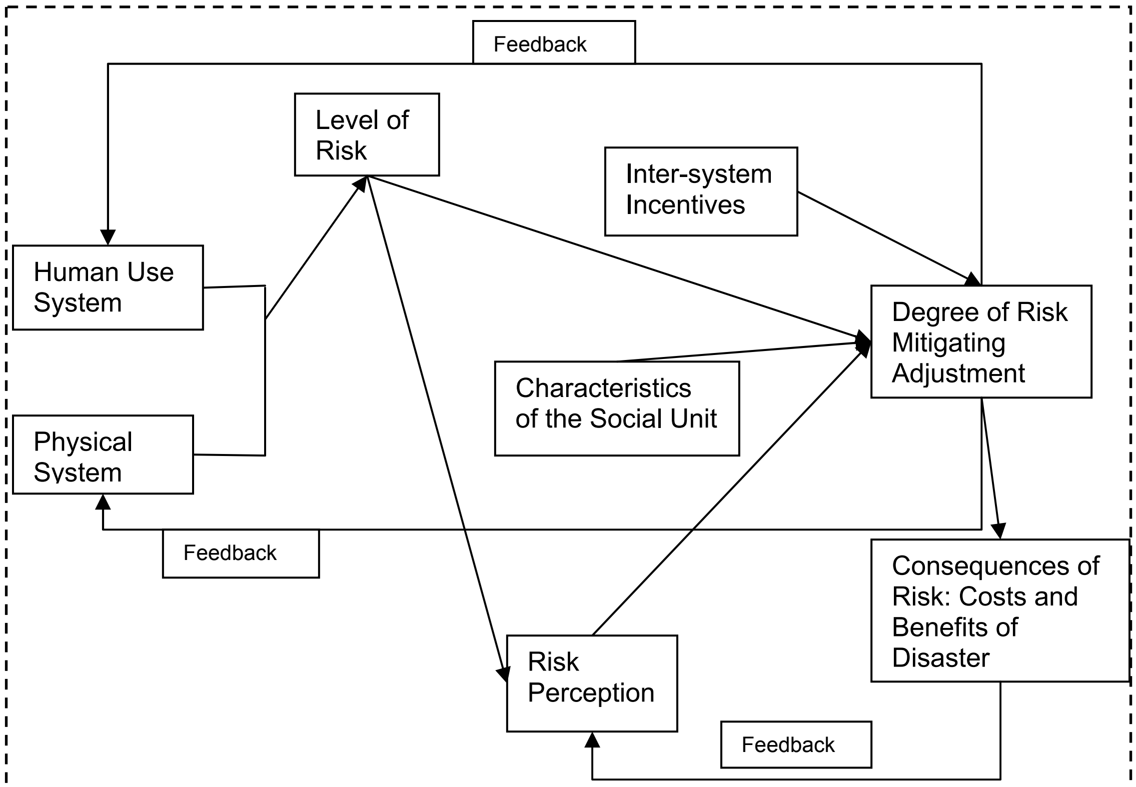

Figure 2-5. Key concepts in the emerging theory of risk mitigating adjustment (adapted after Mileti (1980)).

Embracing the central thrust of hazard research that the formulation of hazard mitigation policies and adoption of effective risk-abating adjustments is a positive function of risk perception, many researchers have tried to explore the underlying determinants of risk perception. Summarizing the findings of studies conducted before 1980, Mileti comes up with a list of six influencing factors of risk perception: a) ability to estimate risk, b) causes of environmental extremes perceived as natural, c) experience with risk, d) propensity to deny risk, e) size of the unit of analysis, and f) access to information (1980: p. 338).

Begun with the study of floodplains in about the mid-twentieth century, research on risk perception now spans many hazard types. Perception of technological risk became a prolific domain in the 1970s and 1980s. Originated in empirical studies of probability assessment, decision making processes, and utility assessment (Slovic, 1987), psychological research on technological risk was guided by a common approach popularly known as the psychometric research paradigm. Proponents and practitioners of this paradigm (Fischhoff *et. al.*, 1993; Fischhoff *et. al.*, 1978; Slovic, 1987; Slovic *et. al.*, 1985; Gardner and Gould, 1989; Sjoberg, 2000) sought to identify the characteristics determining people's risk perception, and to offer psychological explanations for the variation of perceived risk among individuals. Characteristic steps followed in the psychometric approach are: a) a list of hazard items is prepared; b) a psychometric scaling is devised to measure risk; c) people are asked to evaluate risk on the scale; and d) results are calculated using multivariate analysis techniques in order to specify the influencing factors of risk (McDaniels *et. al.*, 1995; Sjöberg, 2004).

In the realm of physical hazards, risk perception and awareness surveys were conducted for different hazards in different places of the world. Various underlying causes, aspects, and consequences of hazard/risk perception have been investigated employing empirical studies on flood hazard (White *et. al.*, 1958; White, 1964; Burton *et. al.*, 1968; Burton, 1962; Kates, 1962), earthquake (Mileti and Darlington, 1997; Turner *et. al.*, 1980; Turner, 1983; Simpson-Housley and Bradshaw, 1978; Simpson-Housley, 1979b; Jackson and Mukerjee, 1974; Hewitt, 1976), wildfire (Gardner *et. al.*, 1987), volcanic eruption (Saarinen and Sell, 1985; Greene *et. al.*, 1981; Tobin and Whiteford, 2002; Gregg *et. al.*, 2004; Dominey-Howes and Minos-Minopoulos, 2004), drought (Saarinen, 1966; Liverman, 1978; Taylor *et. al.*, 1988), snow hazard (Earney and Knowles, 1974), tornado and cyclone (White, 1974; Mitchell *et. al.*, 1989; Hanson *et. al.*, 1979), and hurricane (Cross, 1980). Major theoretical and policy discussions on risk perception of natural hazards have been built based on the findings of these research works.

Flooding dominated the attention of mainstream perception researchers in the late 1950s and 1960s. Groundbreaking works in hazard research such as Kates (1962) and White (1964) focused on the study of hazard perception and awareness of available adjustments of floodplain occupants in the United States. Kates (1962) studied local people and managers of six floodplain occupancies using questionnaires and interviews to understand people's perception of the flood hazard and adoption of adjustment alternatives. Basically, he attempted to answer the question, "Why do people persist in living and working in areas subject to repeated floods despite their perception of risk?" He found that people were prisoners of experience *i.e.* their perception of risk was analogous with experience with flood. They utilized 'bounded rationality' in making adjustment choices. Some of them had poor knowledge of adjustments, and were numbed by certain intrinsic advantages of the floodplain. White (1964) found that there were six other adjustment choices such as emergency evacuation and change in land-use open to floodplain managers, apart from the traditional alternatives of loss bearing and protection through engineered works. Employing decision-making models, he postulated that a manager's (floodplain occupant) decision-making on the adoption of these adjustment alternatives is influenced by six basic elements: a) manager's perception of flood hazard; b) manager's perception of the range of possible adjustment choices; c) perception of technical feasibility required for the implementation of the chosen adjustment(s); d) recognition of spatial linkages with other similar floodplains; e) social constraints such as policies of the place; and f) economic efficiency of the adjustment. Recent occurrence of big floods was found to be directly related to the enhanced implementation of emergency adjustments.

Empirical studies on perception of flood hazard were conducted also in the Europe and other developed countries like Japan. A survey study by Smith and Tobin (1995) in Northwest England revealed that perception of flood risk of respondents was highly shaped by their experience with the past floods. It showed that younger floodplain residents had elevated confidence in structural mechanisms for control of flooding. Studying the perceptions of a floodplain urban community in Portugal, Nunes Correia *et al.* (1998) found that almost all the residents were aware of the hazard and could tell stories about past floods. However, they (mostly shopkeepers) had low risk perception. They were optimistic and showed risk denial. Using mailed survey, Siegrist and Gutscher (2006) studied risk perception of floods and preparedness in Switzerland. They found that people's risk perception was correlated with expert risk assessment. In some regions people overestimated the risk of flooding while in others they were found to have underestimated the risk. Employing a questionnaire-based survey in Nagoya City, Japan, Motoyoshi *et al.* (2004) attempted to examine the underlying factors influencing preparedness for flood risk. Unlike major findings in the literature, they concluded that "one's flood experience and flood anticipation do not necessarily contribute to one's preparedness for floods." However, fear of floods (risk perception), not anticipation, positively enhances preparedness activities.

Research works on perception of the flood hazard were conducted in developing countries also. Ologunorisa and Adeyemo (2005) conducted a survey study to understand the perceptions of floodplain residents in the Niger Delta. Their results show that most of the respondents were aware of the flood hazard, and thought heavy, prolonged rain to be the main cause of big floods. The people said they were living in the hazard zone for subsistence fishing and agriculture. They were unable to afford to living in safer place. Based on a survey of farmers living in Jamuna floodplain of Bangladesh, Paul (1984) discovered that perception of flood risk was in line with their experience with past floods, and the farmers could cope with ordinary floods using traditionally practiced adjustments. Victims of the 1994 flood in Guangdong, China, were interviewed by Wong and Zhao (2001). They found that most of the respondents were doubtful of large, engineered solutions of floods. Embracing the concept of 'living with floods' they opined that flooding in their villages was unstoppable. Based on the respondents' views, the researchers recommended that nonstructural *i.e.* functional, adjustments be adopted and sustainable hazard mitigation approaches promoted.

Research on risk perception of flash flooding is sparse. Gruntfest *et al.* (2002) conducted mailed and internet surveys in order to determine perceptions, needs, and risk awareness of the people living on the Boulder Creek floodplain, Colorado, which is prone to sizable flash floods and has a comprehensive flood warning system in place. They concluded that the respondents know that they are living in a floodplain, but have a low awareness about flash flooding. People living for less than 1 year in the area had low risk scoring; males under 35 years felt less fear of flash floods; a majority of women felt personal risk while the majority of men felt risk to property. Wagner (2007) studied people's perceptions of flash floods in four communities of the Bavarian Alps, employing a 'mental models' approach. He found that heightened level of hazard was perceived by those who had knowledge about the causes of flash floods, gained information through multiple sources, and had previous experiences with flooding. With an aim to measure the current state of knowledge and awareness of people about flash floods, Knocke and Kolivras (2007) carried out a survey in the New River and Roanoke valleys of southern Virginia. They concluded the respondents had an understanding about the rapid onset and shortness of flash flood events. They knew heavy downpours to be the causal factors of flash flood but did not mention dam failure or rapid snowmelt as causes.

This review of the risk perception literature demonstrates that research on risk perception of glacial lake outburst flooding (GLOF) is nonexistent. My research aims to fill this research gap by studying the perceptions of people living in valleys downstream from a potentially dangerous glacial lake in Nepal. While accomplishing this goal, I also attempt to answer the following questions: a) are the findings of existing research on other types of hazard applicable to or compatible with the findings of my study on risk perception of outburst flooding?; and b) are the research findings obtained from urban communities in developed countries similar to the research findings obtained from rural communities in developing countries like Nepal?

I will describe in detail the research methodology I employed, and the sites of my study in next chapter. However, I will provide a discussion on the GLOF phenomenon and a review of literature on GLOF in the following section before delving into research methods.

2.2 Glacial Lake Outburst Flood (GLOF)

A glacier is "a large, perennial accumulation of ice, snow, rock, sediment and liquid water originating on land and moving down slope under the influence of its own weight and gravity" (Molnia, 2004). Pronounced retreat of glaciers since the 1920s have been observed in the Andes (Lliboutry and Arnao, 1977), the Alps (Huggel *et. al.*, 2002; Huggel *et. al.*, 2004), the Himalayas (Ageta *et. al.*, 2001; Chikita, 2004), Tibet (Xu, 1988; Chen *et. al.*, 2007), British Columbia (Clague and Evans, 2000), and Alaska (Post and Mayo, 1971). As a result, glacier-impounded lakes became prolific in those glaciated regions. A glacial lake, by definition, is "an accumulation of standing water on (supraglacial), in (englacial), and under (subglacial) a glacier" (Molnia, 2004). Of these three major glacial lake types, supraglacial lakes have been studied more widely (Tweed and Russell, 1999). Supraglacial lakes are further described as ice-dammed and moraine-dammed types in glaciological literature.

The expansion and recession of glaciers is dependent on global temperature fluctuations. In the postglacial past (last 10,000 years), there likely were warmer periods, which may have also caused rampant glacier recession and higher GLOF occurrences. In the Little Ice Age (some 300 years ago), glaciers markedly expanded. And again with the global temperature rise in the present time, more GLOFs are likely to occur. Owing to the accelerated recession of glaciers, glacial lakes are expanding vertically, as well as horizontally, *i.e.* both in volume and size. When the hydrostatic pressure of the increasing lake volume exceeds the restraining cryostatic pressure (in case of ice-dammed) and lithospheric pressure (in case of moraine-dammed), a catastrophic failure of the lake is likely to occur, resulting in an outburst flood (Richardson and Reynolds, 2000). Various trigger mechanisms such as overspill, displacement wave from ice calving or rock avalanche, earthquake, subglacial volcanic eruptions, and ice-dam floatation are mentioned in the literature (Tweed and Russell, 1999; Sakai *et. al.*, 2000).

These floods from the failure of glacial dams are recognized and studied under different names: Jokulhaup in Iceland and Norway, Aluvion in the Andes, Debacle in parts of the Alps, and GLOF in the Himalayas and Tibetan Plateau. Although these terms are often used synonymously to mean the phenomenon of cataclysmic failure of glacier dams, each of them bears a specific connotation. For example, Jokolhaup refers to the outburst of englacial lakes triggered by volcanic explosion underneath a glacier. Aluvions traditionally are disastrous debris flows irrespective of their causes (Lliboutry and Arnao, 1977). GLOFs are often caused by the breaching of terminal moraine-dammed lakes (Xu, 1988).

2.2.1 GLOF in the Himalayas

In the Himalayas, moraine-dammed glacial lakes are the dominant type. Mainly, GLOF events have been recorded in Central and Eastern Himalayas (Mool *et. al.*, 2001). Although the catastrophic drainage of glacial lakes must have been ongoing phenomena ever since the existence of glaciers, their recording is a recent activity. Based on data available in the existing literature, 17 GLOFs occurred in Nepal since the 1960s (Kattelmann, 2003). Thus, one glacial lake breaches every three to four years. The common occurrence of GLOF in Nepal is substantiated by the fact that local Sherpas term it 'Chhugyumha,' which means 'a sudden flood' (Vuichard and Zimmermann, 1987). There are 2,323 glacial lakes in Nepal at present, of which 20 have been identified as potentially dangerous (Mool *et. al.*, 2001). As most of the existing lakes are swelling in size and volume, and their moraine dams degrade, the likelihood of bursting is increasing. Tsho Rolpa is one of the largest and most dangerous lakes, occupying an area of 1.76 square kilometers (DHM, 2000). It is the only glacier lake in Nepal where a comprehensive GLOF mitigation program has been launched. My research focuses on the communities downstream from this glacial lake.

2.2.1.1 Tsho Rolpa Glacial Lake

Tsho Rolpa is located about 110-km northeast of Kathmandu at an elevation of 4580 m in the Rolwaling Valley of Dolakha District, Nepal (Figure 2-6). The lake has been dammed by a 150 m high unconsolidated end-moraine, and is growing bigger every year owing to melting of the Trakarding Glacier terminus (DHM 2000). The moraine complex is partly cored by stagnant glacier ice, and the lake is expected to breach at some time in near future, releasing millions of cubic meters of water within a few hours (Reynolds, 1999). This lake appeared as a cluster of small supra-glacier ponds that merged in the 1950s and grew to its present voluminous stage (Mool, 1995).

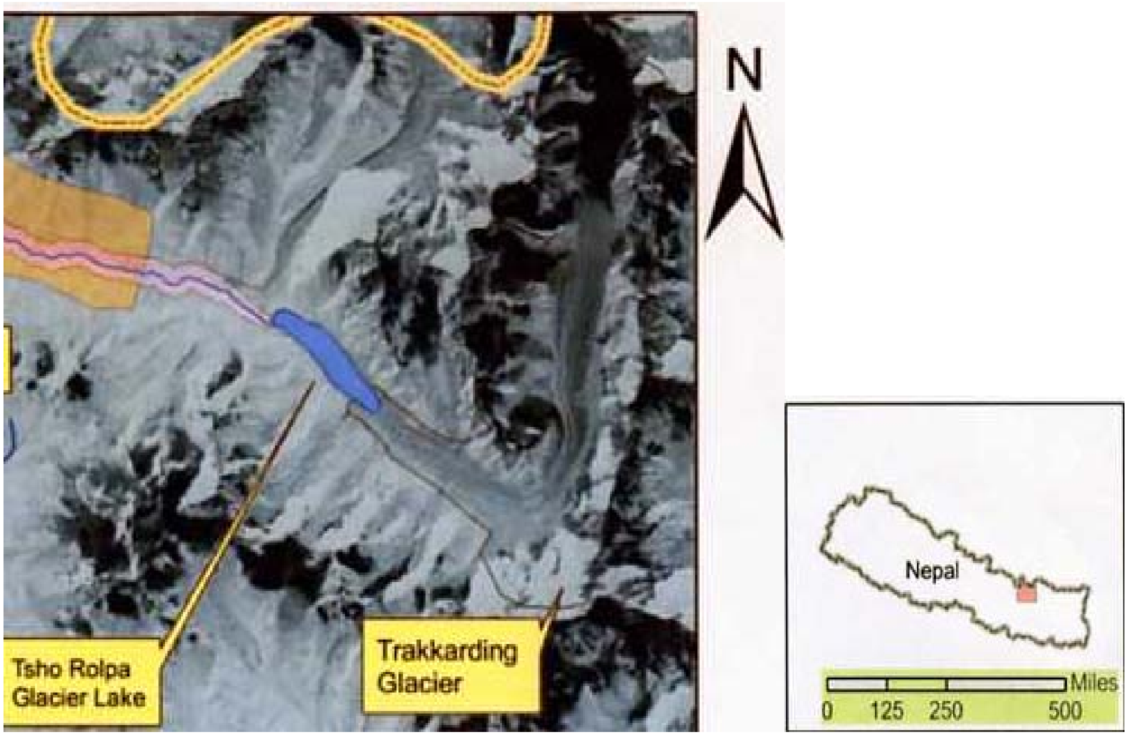

Figure 2-6. Tsho Rolpa glacial lake and the mother glacier – the Trakarding. Rolwaling River originates from the lake. The smaller figure on the right shows the location of Tsho Rolpa Lake in Nepal. (Map created by the author with data from GIS Data Depot, Geo-Community. "Copyright 1995-2000 The GeoCommunity. All rights reserved." Refer to Appendix B.)

Owing to an ice avalanche, Chubung Glacial Lake, located near Tsho Rolpa breached in July 1991. The ensuing flood wave in Rolwaling River killed one person and caused huge damage in the villages of Na and Beding (Damen, 1992). This GLOF instigated concern about Tsho Rolpa, which was at least six times larger than Chubung, among Sherpa residents of Beding. They sought outside help. With the assistance of Dutch and Japanese researchers, studies were conducted in series in 1992 and 1993 to measure the lake volume and assess the hazard (Mool, 1995; Yamada, 1993). In 1994, a more comprehensive study was conducted jointly by Nepalese researchers with British scientist J. M. Reynolds (Reynolds, 1999). All of these studies concluded that Tsho Rolpa poses GLOF risk.

In response to the Tsho Rolpa GLOF hazard, various mitigation strategies have been adopted. An experimental siphon system was installed in July 1995 with the financial and technical assistance of the government of The Netherlands. The trial installation evacuated lake water at a rate of 170 liters/second, and worked for 14 months (MountainLegacy.Net, 2001). Yet, experts estimated that the evacuation of water would have to be about 30 times greater in order to lower the water level by three meters. In June 1997, the Nepal Government installed five locally manufactured siphons and made an ad hoc arrangement for providing manual early warnings to the downstream communities (Reynolds, 1999). Army and policemen were deployed at the lake, and employee from the Department of Hydrology and Meteorology (DHM) would report information on lake activities to Kathmandu, which in turn would be broadcast by radio in case of a GLOF event. In the following months, evacuation alerts were issued for the people of the at-risk zone. Although the evacuation was not mandatory, most of the residents moved from their residences to safer places for at least one month. Nothing happened, and they returned at the end of the summer season.

An early warning system was established in May 1998. A series of remote sensors was installed along the Rolwalling and Tamakoshi river valleys. Sirens were installed in 17 endangered villages. The villagers would be alerted by sirens, which would automatically sound in case of a GLOF event (MountainLegacy.Net, 2001). A GLOF risk reduction project funded jointly by the World Bank, the Netherlands International Development Agency (NIDA), and the government of Nepal started work in 1998 to lower the lake level by 3m, thereby helping reduce the immediate risk. The project, which completed in June 2000, has constructed a 3m deep artificial channel through the western end moraine, bringing down the water level by three meters (DHM, 2000). The next stage of the project should lower the water level by 15-17 meters to make the lake safe (Kattelmann, 2003; Reynolds, 1999).

2.2.2 Outburst Flood as Hazard

Sudden and catastrophic drainage of glacial lakes have continued as the extreme natural events in glaciated regions of the world since historic times. A colossal Jokulhaup drained from ancient Glacial Lake Missoula. Recorded histories show that big Jokulhaups occurred in Iceland, Greenland, Norway and other glaciated areas. Massive glacial floods have commonly occurred in recent times as well. For example, a Jokulhaup occurred in Iceland in November 1996, and huge glacial outburst surges occurred from Hubbard Glacier of Alaska twice: in May 1986 and in August 2002 when the Russell Glacial Lake catastrophically ruptured (Alden, 2004; Trabant, 2002). In Nepal, a big glacial flood inundated the whole floodplain of Seti Khola, Pokhara in about 1555 (Richardson and Reynolds, 2000). However, these events were hardly disastrous in spite of their size, that is, these GLOFs were only extreme natural events, not disaster events. This was because they occurred in remote and even pristine regions. In British Columbia, many glacier-related floods are still observed and studied as geological and glaciological events, rather than as hazards (McKillop and Clague, 2007).

Since the first quarter of the twentieth century, people started to move into valleys in the high mountainous regions downstream from glacier lakes due to population pressures and in search of economic opportunities. As a result, any occurrence of outburst floods from such lakes is likely to affect people downstream. GLOF is now a major glacial hazard particularly in the Peruvian Andes, the Himalayas, and the Alps.

The literature on GLOF hazard is young, though burgeoning. Most of the published research works on cataclysmic outburst floods so far have focused on geophysical aspects of glacier lakes and mechanisms of outburst floods (Ageta *et. al.*, 2001; Chikita, 2004; Chen *et. al.*, 2007). Some of these researchers have concentrated on examining and measuring the horizontal expansion of glacial lakes for determining the potential outburst (Watanabe *et. al.*, 1994), while others have investigated bathymetric changes of the glacial lakes (Benn *et. al.*, 2001; Chikita *et. al.*, 1999; Sakai *et. al.*, 2005). A few others have collected post-event data, and have described characteristics and consequences of GLOF disasters (Ives, 1986; Lliboutry and Arnao, 1977; Vuichard and Zimmermann, 1987). Mool *et. al.* (2001) have come up with inventories of glacial lakes in the Himalayas, and have categorized some of these lakes as posing risks to downstream valley dwellers.

Only a few works to date have focused on assessment and mitigation of the GLOF hazard to concerned communities. Richardson and Reynolds have presented an overview of hazards in the Himalayas, and mentioned glacial dam-burst flood as one of the major hazards. They suggest three phases of GLOF hazard management: i) identification of the potential hazard; ii) monitoring and assessment of the hazard; and iii) development and implementation of a remediation plan (2000: p. 40). They do not touch on other hazard adjustment strategies. Likewise, Kattlemann (2002) argues that GLOF hazard can be managed by lowering the water level through constructing channels on moraine wall.

Studies have been conducted on the GLOF hazard in the Himalayas and other regions of the world, but no one has studied risk perception of the affected communities. From section 2.1.4.2 above, it is clear that a number of studies have been performed on risk perception, but no one has focused on the GLOF hazard. My present research attempts to fill the research gap by studying the risk perception of people living downstream from Tsho Rolpa.

Chapter 3: Methodology

Based on research on other natural hazards, it is reasonable to assume that outburst flood hazard mitigation and disaster preparedness actions are positively related with the pre-event risk perception of local people and public managers. If the downstream communities perceive a heightened level of risk, then they influence hazard mitigation at least in two ways: they can exert pressure on government and donor agencies for funding (in the case of a country like Nepal); and they can adopt disaster preparedness on their own at the local level. It is important to understand if the downstream populations are aware of the probability of Tsho Rolpa outburst flood and perceive the risk of being flooded at a time when experts involved in hazard assessment claim that the lake still poses high risk, despite some preliminary mitigation works. The government and donor agencies also are turning a deaf ear to the problem. The present study has the goal of determining the risk perception of the population living in the hazard zone.

3.1 Methods of Data Collection

For the abovementioned purpose of probing risk perceptions of the people of the Rolwaling and Tamakoshi river valleys (Figure 3-5), I used field observation and semi-structured interviewing as the major methods of data collection. Often employed by hazard perception researchers, these qualitative methods are suitable for gleaning ideas and beliefs of the public. Additionally, informal conversations with local leaders, teachers, staff of local offices, NGO workers, and an employee of the office of the Department of Hydrology and Meteorology (DHM) in Kathmandu were equally helpful sources of information to me.

I gathered valuable information on the Tsho Rolpa GLOF hazard as a field observer - sometimes as a participant but most often as a non-participant observer. An example of a participant observation activity was my attendance at a public meeting at Singati. Although the meeting focused on how construction of a proposed road that would run along Tamakoshi River should be expedited, I could infer some ideas about the people's perception of the risk of flooding. I also took stock of physical, geographical, and environmental features of the valleys, apart from socio-economic and demographic characteristics of the populations living in there. My attention was concentrated on observing those features and conditions in the valleys that determined the vulnerability of local communities to flooding. I observed the proximity of houses and other structures to the river at some places (Figures 3-1 & 3-2), and width and slope of the valley at others. Sometimes, my eyes were caught by some structural mitigation efforts (Figures 3-3 & 3-4) that would paradoxically increase people's vulnerability to flooding (see Chapter 5). I also made observations about the location, size, and condition of Tsho Rolpa Lake itself. Although the moraine wall that has impounded lake water looks wide and strong to the eye, an observer can also feel the probability of dam-failure. If one notices carefully, the massive water body looks perched on a down sloping gorge between mountains and is dammed by a steep, tall end-moraine. The moraine wall at the western end where the artificial spillway has been constructed is narrower and slack, consisting of boulders and rock.

Figure 3-1. Northern end of Singati Bazaar that is susceptible to a probable GLOF event.(Photo by author)

Figure 3-2. Houses, trail, and infrastructures such as the suspension bridge that are in the GLOF hazard zone at Jagat. (Photo by author)

Figure 3-3. Structural mitigation adjustment to protect Khimti Hydro-power plant at Khimti (Photo by author)

Figure 3-4. Gabion wall erected as part of mitigation efforts at Gongar (Photo by author).

Through casual conversations with different people, I acquired information on the chronology of the Tsho Rolpa Lake Mitigation Project, and installation of a siren system in at-risk villages along the river valleys. Before leaving for my field visit, I spoke with an employee at the DHM who was involved in the project. He apprised me of current mitigation activities on the Tsho Rolpa GLOF hazard, and explained the government's effort to effectively disseminate flood warning to probable victims at a time when the previously installed early-warning sirens have been uninstalled by former Maoist rebels. He said the DHM employees, who are deployed at Tsho Rolpa Lake, would give information on any lake-breach to the central office in Kathmandu, which thereafter would be instantly broadcast through radio and television.

Similarly, I learned more about the month-long evacuation of 1997 through talks with local teachers, youth club members, staff of some local offices, and village leaders. I got chance to talk with them at tea-houses, pub-houses, market fairs, public telephone offices etc. I also conversed with local people while on the walking journey along the riverside trail to reach one riparian village from another. Often, I talked with fellow trekkers for hours while resting from the stress of backpacking. Likewise, I would not miss any chance to indirectly ask people about flooding at the inn where I would stop for a night or more. These congenial interactions made it possible for me to build rapport with the people and make judgments about whom I could select as possible interviewees.

Semi-structured interviewing was the major method of obtaining information from people in my research. It allows flexibility for the interviewer to ask pertinent follow-up questions and for the interviewee to raise new topics of interest, while providing uniformity of collected data that enhances comparability (Jackson and Ingles, 1998). The semi-structured interview is thought to be an appropriate technique to gather qualitative data about human perceptions and their behavior at the time of disaster events. An interview template, a set of open and close-ended questions, sometimes followed by probes, was prepared in advance of conducting interviews. The interviews were held during one month starting from June 15, 2007. The interview schedule (Appendix A) consists of 23 questions. The first six questions are general and seek information mainly about the demographic and geographical characteristics of the respondents and their villages. These questions were also designed to ease the conversation and set a comfortable interview milieu. Comprising the core of the set, the next 10 questions were formulated to explore respondents' awareness of GLOF hazard, and their perception of risk. The third part, consisting seven questions, was intended to gain insight into the level of knowledge of the respondents about GLOF adjustments and completed mitigation works. There are also questions on people's awareness on global warming and policy recommendations.

I obtained Institutional Review Board (IRB) approval to use human subjects for my research from June 2007 through June 2008. The IRB Protocol number is M0231. A total of 62 individuals were interviewed (sometimes the respondents were more than one, *e.g.* a wife, husband and a neighbor, but I counted it as a single interview). Some of the interviews with women respondents were conducted by my wife, which was effective in gaining rich information. Typically, women in rural Nepal are reluctant to talk with a male outsider. My guide, who was from the local area, helped facilitate my interviewing with respondents whose first language was not Nepali, particularly in Jagat, Gongar, Chheched, and Beding – the uppermost villages downstream from Tsho Rolpa.

Thirty-six of the interviewees (58%) were men; 26 (42%) were women. They were drawn from all four castes: Tagadharis (Brahmin and Kshetries), Newars, Matwalis, and Dalits. Age of the interviewees ranged from 18 to 76 years. Occupation included farming, herding, animal husbandry, business (local groceries and inns/hotels) and office employment. Most of them were following a combination of two or more of these occupations. Regarding education, respondents ranged from illiterate to high school graduates. Income for none of them exceeded $ 300 per month. Of the total respondents, 37 (60%) were immigrants to the valleys, 20 (32%) were born there, and 5 (8%) were temporarily living there as part of their job posting. Four of the respondents were from Beding, 5 from Cheched, 7 from Gongar, 6 from Jagat, 7 from Suri Dovan (Bhorle), 20 from Singati, 5 from Tamakoshi Bazaar, 4 from Khimti, and 4 from Manthali.

3.1.1 Site Description

As shown in Figure 3-1, the Rolwaling River, which is fed by Tsho Rolpa Lake and melt water from other glaciated parts, is a tributary of the Tamakoshi River. Riverine villages in these two valleys are at risk of Tsho Rolpa outburst flooding. Situated at an elevation of 3800 meters, Beding is on the north bank of the Rolwaling River, some 10km downstream from Tsho Rolpa (Figures 3-5 and 3-6). A Sherpa community, Beding is most susceptible to flooding in case of Tsho Rolpa failure because it is close to the river and there will be no lead time for the people to receive any warning. Normally, it takes a three-day trek to reach this Sherpa heartland from the nearest road link. There are about 20 houses likely to be damaged by a probable GLOF. Chheched (Figure 3-5) is at the bottom of another slope of the narrow Tamakoshi River valley at the confluence of these two rivers. This village comprises seven households of Sherpa people and is at an elevation of 1490 meters. Both Gongar and Jagat are on the right (west) slope of the Tamakoshi River further downstream. Gongar is a cluster village of about 15 houses, and Jagat is divided into Upper Jagat and Lower Jagat, with scattered households. Bhorle is about 10 km further downstream from Jagat, on the left (eastern) side of the river. The elevation declines significantly as the river travels southward. The further downstream one goes, the wider the Tamakoshi river valley becomes. By the time Tamakoshi arrives at Bhorle, its valley slopes are quite flattened.

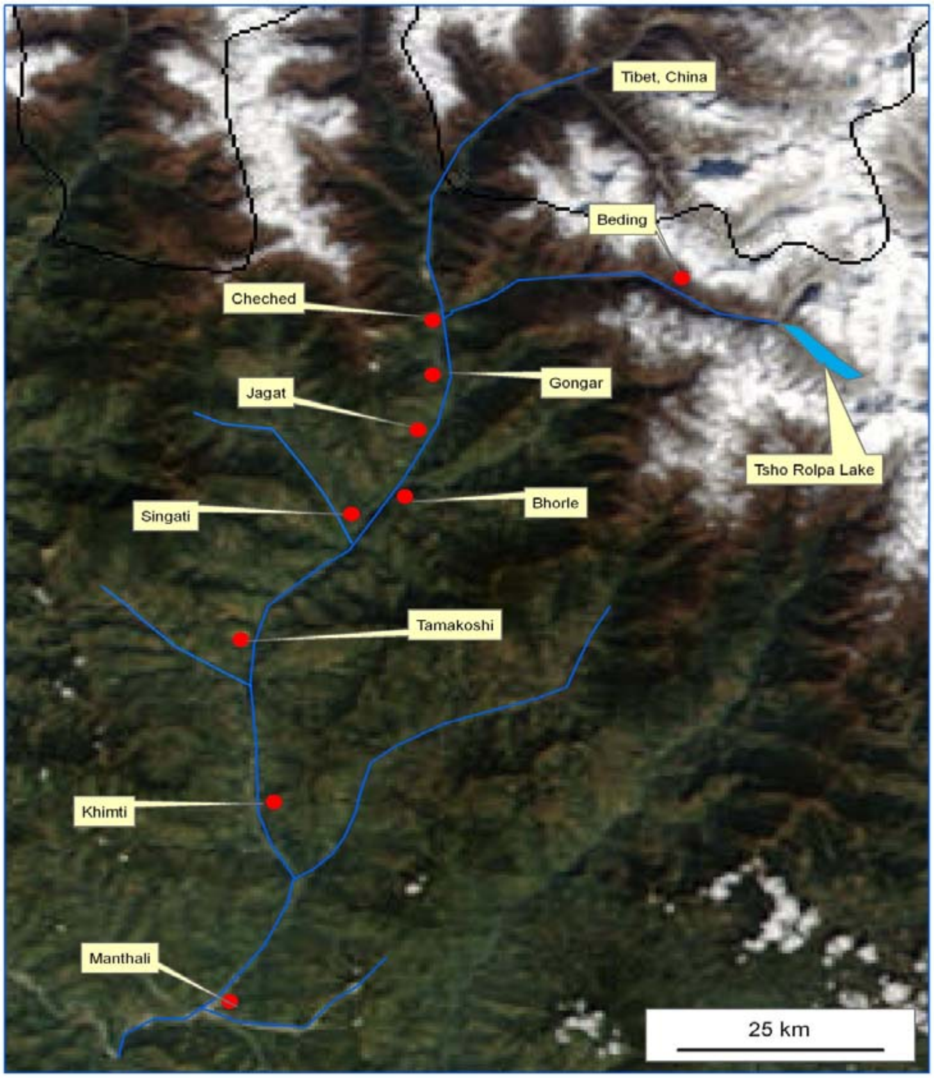

Figure 3-5. An overall view of riverine villages (study sites) in the Rolwaling and Tamakoshi river valleys downstream from Tsho Rolpa Glacial Lake. (Map created by author with data from MODIS images on 'Visible Earth,' NASA). Refer to Appendix B for copyright information.

Linked to a road, Singati is the doorway to a journey to the abovementioned villages. I started interviewing local people from this place after my arrival by bus. As it is a small trade junction, I found people to be more responsive and open than those who are from the abovementioned villages. It is a bazaar area of clustered houses built for keeping shops, groceries, tea-houses, pubs, inns and the like, so most of the respondents from here mentioned business as their occupation. I spent a comparatively longer time at this place conducting interviews with people.

Tamakoshi Bazaar is a stopping place for road traffic including passenger buses that ply to and from Kathmandu and eastern parts of the country including Jiri and Manthali. It is at the western mouth of a concrete bridge that crosses over the Tamakoshi. All the respondents said they do a sort of subsistence business operating local groceries, lodges or pubs. About 50 household families live in the GLOF hazard zone. Situated at an elevation of 650 meters, Khimti is a 60-megawat hydropower plant on the bank of Tamakoshi. The powerhouse, office buildings, and employee quarters are within the flood hazard zone. I interviewed a few employees of the hydro-project. Manthali is the headquarters of Ramechhap District (Figure 3-7), and is at an elevation of 500 meters. Part of it is at the bank of the river, mainly an airport and about 100 houses. All of these three places are linked to motorways.

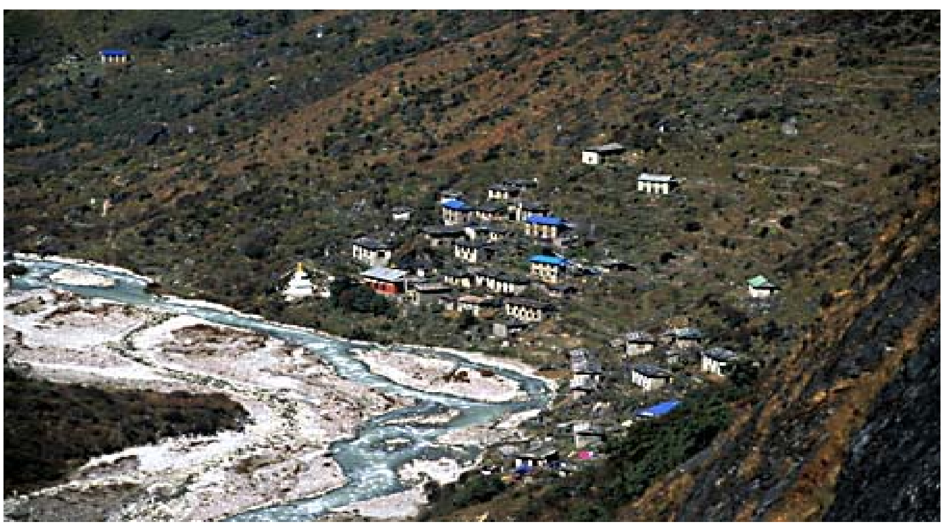

Figure 3-6. A glimpse of Beding, which is on the bank of Rolwaling River. (Photo by author)

Figure 3-7. The grassy runway of Manthali airport, fertile cropland and a part of the town of Manthali, lying within the GLOF hazard zone. (A photo by the author).

3.2 Sampling of the Study Sites and Population

Random or probability sampling, which ensures an independent chance of selection of samples from the universe, is a common sampling technique adopted by hazard perception researchers. The samples are representative of the total population, and the data obtained are unbiased, can be generalized, and are suitable for statistical tests based on the theory of probability (Kumar, 2005). Yet, this procedure could not be used for the selection of both communities and samples in my study owing to specific characteristics of the research area and resource constraints.

The sampling population (universe) consists of an estimated 7,000 people living along the Rolwaling and Tamakoshi river basins extending up to 1,00 km downstream from Tsho Rolpa (MountainLegacy.Net, 2001). There are some 20 riparian towns and villages lying scattered within the hazard zone as delineated in the time of 1997 evacuation. The hazard zone had been roughly defined to be the area 20 meters high at both sides from the stream channel. Some of these villages are larger with populations up to 3,000 and others have only two or three households within the at-risk area. So, selecting downstream villages through probability sampling could be difficult. Moreover, some villages like Na were impossible for us to reach. Similarly, it was almost impossible to obtain names of all the people living in the area. If census data were obtained from the Village Development committees (VDCs), there was no indication of who lived in the flood hazard area. For example, I could obtain the population of Singati VDC, but not all fall within the hazard zone. There are no data for the people living in hazard zone only. Furthermore, it was not certain that I could interview each person selected by random sampling because he/she might have been out of the village, might have gone to work, or might have been reluctant to give an interview. It would have been more demanding in regard to time and resources.

The procedure for selecting interview samples was a combination of judgmental or purposive sampling and snowball sampling. Based on the situation, timing, and availability, I made judgments about whom to interview, which respondent was likely to provide useful information. Sometimes, I depended on chaining to select interviewees. The respondent would suggest the name of a next probable interviewee. Often, he/she would escort and introduce me to the new respondent. This was effective because it helped build rapport and made the new person feel comfortable to converse with me. As I was a stranger, I asked them to identify other people who were interested in talking or knowledgeable about the GLOF hazard.

3.3 Recording and Interpretation of Data

Accompanied by note taking, all the interviews were tape-recorded after receiving permission of the respondents. Interviews in Nepali were first transcribed and then translated into English. Sometimes, translation occurred twice, as a few interviews were in the Gurung language, a local vernacular. My guide transcribed and translated these interviews into Nepali, which I, in turn, rendered into English. The notes, taken during the interviews, assisted in data transcription and analysis. Most of the field observations I made were jotted down in my notebook. I often made spatial sketches of the rivers, locations of the villages, and geographic structures of the valley. Informal conversations were not accompanied by note taking. I wrote these notes at night after I returned to my inn, based on what I could recall. My wife often helped me remember important points.

Interview transcripts were coded and analyzed. Coding was somewhat straightforward. Using Microsoft Excel software, I put in question numbers used in the interview schedule (Appendix A) on rows and names of all interviewees on columns of the spreadsheet. The responses of each interviewee were preliminarily coded and categorized by question number. Sub-codes were devised for sub-categorizing the responses that had been grouped under a certain question number, which represented a theme. For example, all the responses on ‘hazard awareness’ were grouped under the code ‘Q-6’ with either of sub-codes ‘Y’ for yes, ‘N’ for no, or ‘DN’ for don’t know, which basically are the answers to the question “Do you know/Have you heard about the probability of Tsho Rolpa outburst flood?” (Appendix A – 6). Use of a spreadsheet made the comparisons and sorting the coded responses easier. Then patterns were sought within the coded responses, and possible relationships established among variables. The analysis of data and presentation of results was accomplished using simple descriptive statistics such as bar graphs, percentages, and summary tables. The results of the study are presented in the following chapter accompanied by corresponding discussions.

Chapter 4: Results and Discussion

Results and corresponding discussions are presented in ten sections. First two sections provide an overview of hazards of the study area. Section Three dwells upon the people's awareness of the GLOF hazard and their risk perception. Probable influencing factors of the people's denigrated risk perception are also explored. In the remaining sections, perceived risk is analyzed vis-à-vis different social and demographic characteristics such as migrant populations, gender, and caste of the area. To ensure brevity and clarity, the results are summed as percentages and presented in tables and charts.

4.1 Hazards of the Area

One of the objectives of my interview with people was to determine what they consider the most significant hazard in their surroundings. However, before directly asking them what danger(s) they were facing by living there, I inquired about their positive views of their area. The majority mentioned economic opportunities the location had to offer. Mainly, respondents with business as their occupation said the place provided easier access to roads and other business centers, apart from the fact that they saw a better chance of making profits from their shops and hotels. Others, particularly those who were born there, opined that they were living in the place because whatever lands and assets they had since the time of their grandparents were in that particular river valley. Some said there were schools nearby for their kids, and that bazaars and other basic amenities of life were the factors that attracted them there.

When asked if there was any danger/fear (downside) of living in the place, 42 (68%) respondents stated flood to be the primary source of danger. Twelve (19%)

mentioned landslides, insecurity (*i.e.* from thieves, etc.), and Maoists (former rebels of Nepal) as the top dangers of the area, while 8 (13%) said they were perfectly fine with the place without the feeling of any danger.

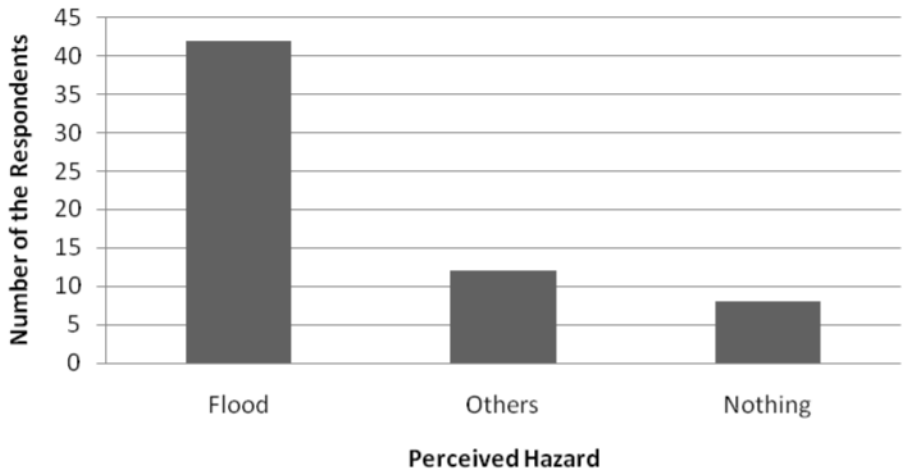

Figure 4-1. Main hazards perceived by the respondents of the study area.

4.2 Responses Related to Flooding

In order to determine respondents' perception of flooding, I asked about flood frequency and magnitude. Most respondents said small to moderate floods are very common every monsoon and a remarkably larger flood comes at an average interval of about 10 years. They opined that moderate floods were never risky to them, but the bigger floods were of substantial danger. Those who denied the presence of any hazard in the area in my previous question stated that the floods are not likely to damage their residences. However, they accepted the fact that such floods might take away their croplands and cause damage to physical infrastructure such as roads, trekking trails and bridges.

Referring to the magnitude of a big flood, they narrated their own stories. What qualified as a 'big' flood was a subjective concept. For some of the respondents, a big flood was one that washed away acres of croplands; for others it had to take away at least some houses and kill people to be called big. For some of them the biggest flood was one which came at midnight with thundering sounds but causing no substantial damage. For others, even a flood that washed away acres of croplands and bridges, and killed a few people, was an ordinary one.

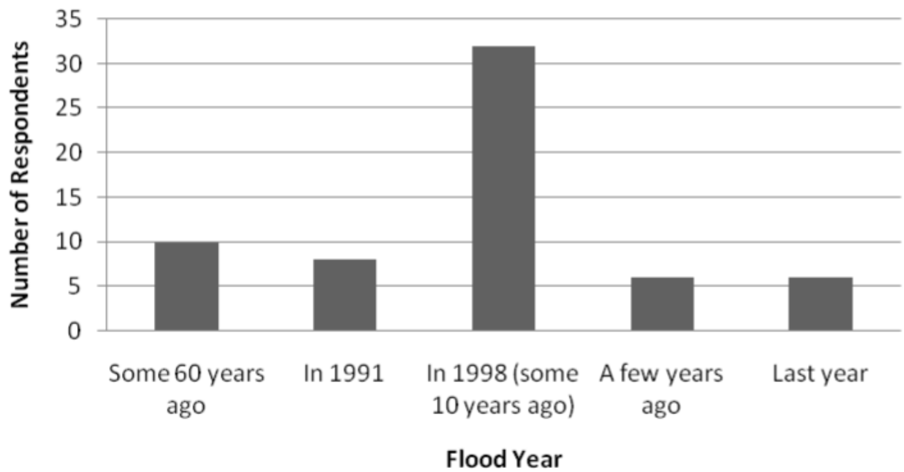

Figure 4-2. Interview responses referring to the year of the largest flood in their nearby river.

In response to a question about when the biggest flood occurred, 8 (13%) respondents mentioned the year 1991. This is the year when Chubung glacial lake drained out and caused a massive flood in the Rolwaling river valley (see sub-section 2.2.1.1). Almost all of these were respondents from Beding and Cheched villages, which are closest to Tsho Rolpa. Thirty two persons (51%) said the biggest flood came some 10 years ago, referring to 1998. Most of these respondents were from Suri Dovan, Singati, and Jagat villages, downstream from Gongar (Figure 3-5). Another 10 (16%) interviewees said it was some 60 years ago when a big flood happened in the river. These respondents were from Tamakoshi Bazaar, Khimti, and Manthali, which are the furthest downstream villages in the study area. A few respondents (10%) answered that the largest flood they saw was in the previous year.

These results bear out the fact that a ‘big’ flood in the upper valley becomes a minor one as the river travels further downstream. This applies at least in the case of the Nepal Mountains, which gradually decline in elevation from north to south. In 1991, Chubung GLOF rocked the Rolwaling valley and caused substantial damages in Beding, but it was felt to be an ordinary flood by the people of the Tamakoshi river valley. When the flooded Rolwaling joined the Tamakoshi near Chheched, its devastating power was reduced because of the wider channel and flattened basin of the Tamakoshi River. The people of Singati for example did not mention it as a big flood. For them, a big flood occurred in 1998 when a large landslide temporarily dammed one of the tributaries of the Tamakoshi River (not Rolwaling), and released large flood surges. Yet, this flood again was not felt to be a big one by the people of Khimti and Manthali further downstream. This fact can be explained through the analysis of geomorphology of the river valleys and flood mechanism. It is not the excessive river discharge that results in a big, *i.e.* catastrophic flood; it is the amount of shear stress and stream power that is more important (Bryant, 2005). Floods in small drainage basins have a heightened amount of stream power, which is primarily the function of width and depth of the channel, amount of discharge, and the gradient of the channel (Baker and Costa, 1987). Even minor discharges result in major floods if the channel is deep, steep and narrow. This is, in fact, the stream physiography of the Rolwaling and upper Tamakoshi rivers. The rivers flow through steep gorges. But as the Tamakoshi River flows southward and toward the lowland, its channel expands horizontally and the gradient declines. This makes the river gentler, and it needs greater discharge to raise its water level, *i.e.* flood height. As stream power abates, sediment load also decreases substantially. So does the erosive power. Hence, a potential Tsho Rolpa outburst flood, which is likely to be destructively erosive along the upstream channel, *i.e.*, immediately below the lake, would become calmer and minor the further it flows southward.

This explanation is in parallel with another finding of the present study. A majority of respondents from upper riparian communities perceived the Tsho Rolpa GLOF risk, while very few respondents from lower riverine villages had the perception of risk (Table 4-1). For example, 75% of respondents from Beding answered that that they were afraid of or realized danger from a Tsho Rolpa GLOF, while all respondents from Khimti and Manthali answered ‘No’ to the question. The risk of a Tsho Rolpa outburst flood is perceived to be minor by the people of Singati, Tamakoshi, Khimti and Manthali. This justifies the fact that hazard perception is a function of proximity of people’s residence to the hazard source. The farther they live from the hazard source, the lower their perceived risk. This supports the findings of numerous studies. Lindell and Perry (1993) observed that perceived threat of volcanoes significantly increased within a month after the volcanic activity began on Mt. St. Helens, and that risk perception was inversely proportional to distance from the mountain. Barnes *et al.* (1979) evaluating public responses during the Three Mile Island nuclear accident evacuation, found that a lower percentage of people at distant sites from the reactor evacuated. This was further supported by the findings of Cutter and Barnes (1982), who concluded that proximity to Three Mile Island influenced the decision of affected residents to evacuate. Similarly, Diggory (1956) conducted a survey of respondents to a rabies outbreak in eastern Pennsylvania. He concluded that fear of the disease, threat-oriented behavior, and number of information sources used by people increased with an increase in proximity of the threat source. These findings are in line with my study.

The risk denial of people (which I will discuss in a subsequent section) who are farther downstream from Tsho Rolpa (*e.g.* residents of Tamakoshi and Manthali) might be due to the fact that they will have enough lead time between the outburst of the lake and the arrival of flood. Obviously, it takes some hours for the outburst flood to arrive to these places due to the distance from the source. By that time, they hope to receive warning messages from radio or TV. Then they could run to safety and save their lives and some portable valuables.

Riparian Villages	Total Number of Respondents	Respondents Who Perceived GLOF Risk	Approximate Distance downstream from the Hazard Source
Beding	4	3 (75 %)	10 km
Chheched	5	3 (60 %)	25 –km
Gongar	7	4 (57 %)	30-km
Jagat	6	2 (33 %)	35-km
Suri Dovan	7	1 (14 %)	40-km
Singati	20	4 (2 0 %)	45-km
Tamakoshi	5	2 (4 0 %)	60-km
Khimti	4	0	80-km
Manthali	4	0	100-km
Total	62	19 (30 %)	100-km

Table 4-1. People's risk perception of Tsho Rolpa GLOF from different villages in the study site.

4.3 Hazard Awareness and Risk Perception

It is not uncommon to find the terms hazard and risk mentioned interchangeably in hazards usage. Yet, as discussed in Chapter 2, I have used these terms with different meanings for the convenience of explaining my findings. While hazard implies the potential threat of an extreme event, risk accounts for the probability of its occurrence (Okrent, 1980; Smith, 2001; Tobin and Montz, 1997). Additionally, vulnerabilities of people, expected exposure, and mitigation works also are to be considered while determining risk. Results show that almost all respondents of the present study were aware of the existence of Tsho Rolpa GLOF hazard, some of them even saw the probability of the lake-breach, but only a few perceived the risk. That is, the majority of them said they were not afraid of Tsho Rolpa outburst flooding (Table 4-2). All the interviewees except one (who was a newly-arrived employee at Khimti Hydro Project) answered “Yes” to the question whether they had known/heard about the Tsho Rolpa GLOF (Question 11 in Appendix A). They were well aware of the existence of the perched glacial lake at the head of the Rolwaling River. Despite their knowledge about the hazard, the respondents do not think the lake has a high probability of breaching. Less than half respondents see the probability of a GLOF event in future (Question 15 in Appendix A). The risk perceivers of the GLOF are even fewer in number. Only 19 (30%) respondents out of 62 answered that they perceived risk of the Tsho Rolpa outburst flood (Question 16 in Appendix A).

Responses	**Hazard (GLOF) Awareness of the Respondents**	**Probability of Dam Outburst expressed by the Respondents**	**Risk Perception of the Respondents**
“Yes”	61 (98 %)	26 (42 %)	19 (30 %)
“No”	1 (2 %)	25 (40 %)	37 (60 %)
“Don’t Know”	0 (0 %)	11 (18 %)	6 (10 %)

Table 4-2: Interview responses on hazard awareness, outburst probability, and risk perception.

These findings are critical to the study as they directly address my research question stated in Chapter 1. The main goal of the present research was to determine the perception of GLOF risk of local people. The interview results show that local people don’t have a heightened risk perception as had been hypothesized. This minimal risk perception of the people is in contrast with the objective risk assessed by technical experts. Those involved in expert hazard assessment state that there is still a high probability of catastrophic failure of the lake, and that the people downstream are at high risk of the outburst flooding in spite of some preliminary mitigation works (see Subsection 5.2.1).

A number of major works on hazard perception literature have sought to explain the contributing factors of risk perception (Gregg *et. al.*, 2004; Kasperson *et. al.*, 1988; Kates, 1962; Kates, 1971; Lindell and Perry, 1993; Mileti, 1980; Motoyoshi *et. al.*, 2004). These works explain why people persistently continue to occupy hazardous locations. Based on the interview responses, I will explain why people have low risk perception of the Tsho Rolpa GLOF in the following sub-sections. The possible determining factors for the people's denial or shallow perception of the GLOF risk is expounded under different sub-headings.

4.3.1 Effect of the Prediction Failure and Unnecessary Evacuation

Unfounded disaster prediction and issuance of warnings that are not followed by an event are problems in hazard management. “Crying wolf” by authorities about the occurrence of a disaster is unintended. “The basic issue of false alarms is that people who evacuate unnecessarily will not evacuate in a future event. Only one evacuation could be ordered and if that proved wrong no one would evacuate a second time” (Sorensen *et al.*, 1987, p. 19). The desensitizing effect of false alarms has been explored by several authors. Based on his extensive experiments, Breznitz (1984) established that the probability of people's involvement in protective behavior and the intensity of such behavior substantially decrease, while indolence between the time of warning and taking protective action increases as a function of repeated false alarms. Anderson (1969), who studied disaster warnings in two communities of California and Hawaii, found that issuance of repeated warnings not followed by disasters was one of the major reasons why it was difficult for maintaining people's willingness to respond to evacuation requests. Turner (1979) found that perception on salience of earthquake hazard and personal preparedness decreased owing to a number of unnecessary announcements about the prediction of earthquakes in southern California. Warnings regarding a potential chemical accident in Bhopal plant had been published and broadcast in media at least for two years preceding the tragedy (Bhandari, 1984). According to Bhandari, these repeated alert messages not followed by accidents were ignored by both the authorities and local residents

The obvious inference of the interview responses and my informal conversations with the people is that they had a low level of risk perception because they had been the victims of the effect of 'the boy who cried wolf.' A number of respondents grumbled that they were repeatedly told to be prepared and to leave their residence during almost every monsoon since 1993. They were even ordered to evacuate the place in 1997, but nothing happened. Media unnecessarily hyped that the GLOF event was just around the corner. Local leaders and police were heavily mobilized in the at-risk villages that year. Many people evacuated. Seventy-four percent of the respondents moved to safe places for at least one month (see Sub-section 4.3.6). This indicates that people had a heightened risk perception at that time, *i.e.* in 1997. They had trust in expert prediction of the GLOF. But now, they think that all of these people – scientists, government officials, political leaders, NGO people, and the police who had been involved in hazard assessment, prediction of outbreak, and issuance of evacuation orders – are untrustworthy. They have little faith in the ability of experts to accurately predict the lake outburst. This disbelief is evident in the response of a man in his early sixties from Singati, who said:

> One or another from Kathmandu and foreign countries came to us nearly every summer since about 1992 and informed that Tsho Rolpa could outburst. Every time they came,

> they said the lake was becoming more dangerous. They also did some work at the lake. They said they siphoned out lake water. So much so, the police came to order us to go to safe place in the summer of 1997. Many of my neighbors moved uphill to a safe place. I also followed them reluctantly. Nothing happened. We returned to our houses after a month. In fact, I had no faith in those outside people. Now, we realize that it was all an airy matter.…Tsho Rolpa does not break. Even if it breaks the flood will not come up to our house.

The failure of the 1997 prediction of outburst and the precipitous decision to issue evacuation orders was the major reason why most of local people today rebuff any talk on the risk of a Tsho Rolpa GLOF. One of the respondents from Suri Dovan said, “These people from Kathmandu cannot forecast about such natural things. Their guess failed. Now, I think the lake does not break because if it was to break it should have outburst that year.” Others opined that it was just a part of the job of some certain people who spread such rumors and try to attract donors. “Now, we are tired of the baseless rumors. I think the alert issued to us to evacuate in 1997 was based on speculation….I have been living here throughout my life, but have not seen any lake-burst flood. I say it was a result of a money-making game on the part of some NGOs, leaders, and foreigners,” stated a male respondent in his late forties from Singati.

4.3.2 Adoption of Dissonant Perception

Based on responses to risk, human personalities are either risk-averse or risk-taking (Wildavsky and Dake, 1990). Normally, if the risk is voluntary, people are inclined to take it, and if the risk is involuntary, they are risk-averse. “The public is willing to accept voluntary risks roughly 1000 times greater than involuntary risks” (Starr, 1969: p.1236). The GLOF risk is, of course, an involuntary one. The local people should have attempted to avoid it by adopting different mitigation adjustments. However, the results show that people seem to have dismissed the risk instead of realizing it and taking protective measures (only 30% of respondents perceive the GLOF risk: Table 4-2). This tendency to deny risk is described in the hazard literature by the phrase ‘dissonant perception' (Adams, 1973). Risk denial on the part of hazard zone residents is a "logical outcome of the need for them to continue to occupy and use the area" (Mitchell 1984: p. 56).

Smith (2001) mentions three models of risk perception, of which dissonant perception is one. He says, "In order to reduce the stress associated with uncertainty, hazard perceivers tend to adopt recognizable models of risk perception with which they are more comfortable" (2001: p. 70). Those who have dissonant perception resort to the denial either by refusing to acknowledge the existence of a hazard or by underestimating the threat (Tobin and Montz, 1997). In the present study, people don't deny the existence of hazard, but relegate the risk, using phrases like 'such an outburst flood is impossible' and 'it cannot cause any harm to us.' An interviewee from Tamakoshi who was a fisherman by occupation said:

> I say I'm not afraid of Tsho Rolpa. The reasons are: first it does not break. If it was to break why didn't it break in these many years? Second, even if it breaks, the water of a pond will not be that big to cause harm when it spreads in a long and wide river path. This will be a small flood when it arrives here. Third, this cannot reach up to us.

This response makes it clear that some of the respondents underestimate the risk by thinking that the hazard event will cause only a minor disruption. They think the event cannot cause harm to them. This finding is analogous to the study of Earney and Knowles (1974) who found that people perceived urban snow hazard in the Upper Peninsula of Michigan only as an agent that could cause minor disruptions, but not serious threat to lives. Some other respondents resorted to fatalistic beliefs and attitudes to deny risk. Those who thought that disasters happen as per God's wishes, and hazard events are the 'acts of God/Nature,' readily shelved the GLOF threat, and the feeling of responsibility to respond to the threat. A female respondent of Singati said:

> "By god's grace we are living here safely up to now, and we hope the same in the future too. They say if god becomes angry and urinates lavishly, then a big flood comes. The lake is in god's adobe (*i.e.* the Himalayas). It's in the playing ground of Lord Shiva. We

> hope He will never be angry with us. We often worship and conduct prayers for Him. He cannot be merciless to us."

Others mentioned nature as almighty. Another woman respondent from Jagat said, "Tsho Rolpa is nature's creation, which can't be that fragile to break and cause flooding in our village." When I analyzed the content of all transcribed interviews, I found that a total of 19 respondents mentioned the words 'god' and 'nature' to explain their views. For them, the GLOF event is under the control of either god or nature. These results are again in line with the results of some major perception researchers who have used the concept of 'locus of control (LOC)' as an explanation of people's risk denials (Baumann and Sims, 1978; Burton *et. al.*, 1993; Schiff, 1977; Simpson-Housley, 1979a). The perceived locus of control for some of the respondents (*i.e.* for those who mentioned nature or god) was external. They thought that their environment (here the hazard source) was not under their control (*i.e.* internal LOC), but was manipulated by external force, that is nature or god. The findings of various studies are equivocal on whether the internal or external LOC influences the risk denial and latency in adopting protective actions. But, my interview results support the view that external LOC instigated threat denial.

Similarly, four elderly respondents used an explanation that was opposite to the concept of what is called 'gambler's fallacy,' thereby discounting the perceived threat of Tsho Rolpa. A woman in her sixties from Singati said: "I have been living here since I got married. No such flood has come. Everybody said Tsho Rolpa would break that year, and we also moved to a place uphill for a month, but nothing happened.…You see, I don't have many years to live. I'm sure no GLOF will occur in the river at least during my lifetime." Sometimes, people eliminate uncertainty and discount perceived threat by transferring responsibility to higher power such as god or government (Burton *et. al.*, 1968). Several respondents used phrases such as ‘It’s in god’s hand,’ and ‘the government is there to protect us’. The tendency of putting off responsibility to take precautionary steps was evident in the words of a local midwife from Singati who said:

> “……What can the local people, who are helpless before such matters that are under nature’s control, do? They can just run away if they get early signals. Whatever should be done will be done by the government. The political leaders, government authorities, and donor people will take care of the Tsho Rolpa problem. I’m not much worried about.”

This dependency syndrome (Tobin and Montz, 1997) was manifest in a number of responses, which led them to think that they were not required to heed the problem.

4.3.3 Numbing Effect of Preliminary Adjustments

Adoption of appropriate adjustments for reducing risk is the main goal of every hazard management endeavor. After the existence of the Tsho Rolpa GLOF hazard came to limelight in 1992, hazard assessments were carried out by different research teams (see Sub-section 2.2.1.1). Based on the assessments, some structural mitigation works were kept in place. In 1995, arrangements were made to siphon out the lake water. In 1997, these diesel-run siphons were repaired, apart from the installation of some additional siphons. In summer the same year, the people at highest risk were advised to evacuate. In 1998, an early warning system (sirens) was established in the at-risk riverine villages. A project, which had the aim of lowering the lake water three meters by cutting a channel through the moraine wall, was completed in 2000. At different places along the rivers, flood defense walls have been constructed.

These mitigation works have created a false sense of security among some of the respondents. People often believe that some sort of engineered mitigation structures are a panacea, meaning no further adjustment such as evacuation are required (Sorensen *et. al.*, 1987). The respondents perceive the problem as solved, which has led them to discount their personal risk. In the words of a respondent from Gongar:

> First of all, the outburst of Tsho Rolpa is unlikely because the lake is dammed by a hill. Moreover, they have made it safe by doing the project there. The lake cannot contain a big volume of water because the water passes through the built channel. This does not let the water level rise. Even if it happens very unluckily, we have built a defense wall (Figure 3-4) to protect our village. The flood cannot be that big to overwhelm this.

Similarly, people particularly of Khimti and Manthali are confident that the mitigation works are enough to make their lives safe from any flood including a probable GLOF. Besides the structural mitigation works, the *ad hoc* management for communicating warnings through radio (see Subsection 2.2.1.1) has further numbed the people. An employee at Khimti Hydro Project expressed his feeling:

> Completion of the lowering of water level in the lake is enough to stop the water force from breaking the lake. In case the lake drainage occurs, the employees of the DHM who have been deployed at the lake will convey the message to the Kathmandu office. Then it is broadcast through radio, which we will listen here. The communication is always reliable at our project site. And we will have enough time to move to safe place before the flood arrives to us. The quarters we are living in are not ours. We have no concern for property loss. So, I am confident, and I don't feel any risk.

The numbing effect of the preliminary remediation measures, which is also described as 'the levee effect' in the hazard literature (Tobin and Montz, 1997), has only postponed the disaster. This has encouraged the shift of development and housing works in the risk prone areas. People perceive the areas to be safe due to the mitigation measures. They are unwilling to adopt precautionary actions owing to the denigrated risk perception. As a result, people's vulnerability to the outburst flooding has increased. A more disastrous GLOF occurs when the mitigation measures ultimately fail. Thus, the numbing effect of the structural mitigation works is illusive and counterproductive.

4.3.4 Hazard Salience

The salience of hazards is not criticized in the hazard research as much as its theoretical or paradigmatic aspect is contested. Yet, some scholars like Wright *et al.* (1979) raised the issue of hazard salience. They questioned if natural hazards were salient human problems. These authors argued that despite the rampant savagery, natural disasters have no discernible effects on most human societies. There are few works in the hazard literature that have explored the topic of hazard salience (Mitchell, 1984). The present study primarily does not dwell upon the issue of hazard salience, but the findings somewhat corroborate the view of Wright. For most of the respondents, GLOF hazard with a high level of uncertainty about a probable occurrence is not a salient problem. They are suffering from prevailing problems of scarcity (poverty), lack of education, diseases, and social/political disfavor. They need to heed the immediate needs and struggle with these inescapable day-to-day problems. The Tsho Rolpa threat is accorded only minor importance in the context of other pressing problems of daily life. Clearly, they have neither time nor resources to spare for any precautionary actions that are aimed at alleviating the future threat. This leads them to dismiss the feeling that they are living in an unsafe location. A woman from Singati, whose husband was a policeman and was killed in one of the clashes with Maoist insurgents, narrated why she started to live there:

> "We were living a somewhat happy family in the village uphill. My husband was a policeman, and everything was okay. But now, you know, I'm all alone to take care of these three kids. I could not start a business with that small compensation I got. With that amount, I could just run a tea and snack shop of this size. I'm not educated to get any job. So, this is the only option I had before me…..For me Tsho Rolpa is not a problem. What I'm concerned about is if I can make a small income that would suffice to sustain us."

Natural hazards become a major concern to the people as affluence spreads (Burton *et al.*, 1968). It is reasonable for the respondents, who are living with a monthly income of less than $100, not to pay any attention to the GLOF hazard. Another respondent from Tamakoshi Bazaar, who has a footpath shop by the bus stop, and who rushes with a tray of things to sell to the passengers every time a bus stops for a few minutes, says why he does not think Tsho Rolpa is a source of danger:

> I don't have house or land for farming or animal husbandry. I cannot get a job because I am not much educated and I don't have any people in Kathmandu in higher posts. The only way of making a living for me is selling water-bottles and the like to the bus passengers as you see. Since it is possible to earn a little every day, I'm living here. In other places, it's hard for me to make this much money. So, Tsho Rolpa is not a problem to be worried about. The problem is making a living.

These responses reflect that the living conditions of the people are similar to the one that is described by the proponents of the structuralist view of hazard (see Sub-section 2.1.3.2). They maintain that people in many local communities of the underdeveloped countries are living in hazard-prone areas because of the marginalization of poor people. As learned in the field study, many people are coming to live in the hazardous zone of the river valleys. Migration of people to the study area is increasing. Thirty-seven (60%) of the respondents said that they migrated to the place in search of economic opportunity.

The informal conversations with local political leaders also support this view. They do not place importance on the Tsho Rolpa hazard; it is a low salience issue. The people also hesitate to define the GLOF threat as real. Often, they behave as if there was no Tsho Rolpa GLOF hazard. Development and security are the principal issues that have drawn attention of the local people and the leaders. "Most people here don't think Tsho Rolpa as a problem worth worrying. Everybody here is worried about development of the area. So, we always put forward the slogans of constructing roads, running drinking water supply projects, opening new schools and hospitals and the like at the time of election," said a local party leader and Village Development Committee member from Jagat. As the particular party-man said, the local people do not put salience on the Tsho Rolpa hazard. If they thought that it was really an outstanding problem, they would have raised their voices and elected the political leaders who had shown commitment to resolving the problem. But this is not the case. Tsho Rolpa has not been an issue in the election

4.4 Gender and Risk Perception

A number of works on hazard perception have focused on the topic of gender differences in risk perception. In the perception literature, men are often described as 'risk-takers' and women as 'risk-avoiders' (Cutter *et. al.*, 1992). Based on a survey study, Stallen and Tomas (1988) concluded that women placed higher value on personal health and wellbeing, and therefore felt more insecure about technological hazards. They are more concerned to the threat of nuclear war, and emphasize the need of disarmament, while men are more pro-force (Silverman and Kumka, 1987; Jensen, 1987). Similarly, women feel heightened risk about land use hazards and are willing to have the government spend funds to solve environmental problems (Burger *et. al.*, 1998).

The fact that women are higher risk perceivers is not unanimously established in the literature. Although gender differences in risk perception of different hazards exist in 'good neighborhoods,' it does not hold in 'stressed neighborhoods' such as those situated next to hazardous waste sites, for example (Greenberg and Schneider, 1995). These authors maintain that the same level of threat is perceived by men and women who are living in the place of real hazards as opposed to those displayed on TV screens. Based on the results of a national survey, Flynn *et al.* (1994) concluded that the level of perceived risk was more or less similar for men and women. Contrary to most existing findings, Arcury *et al.* (1987), who probed into risk perception of acid rain, concluded that men were more concerned and knowledgeable about the problem than women.

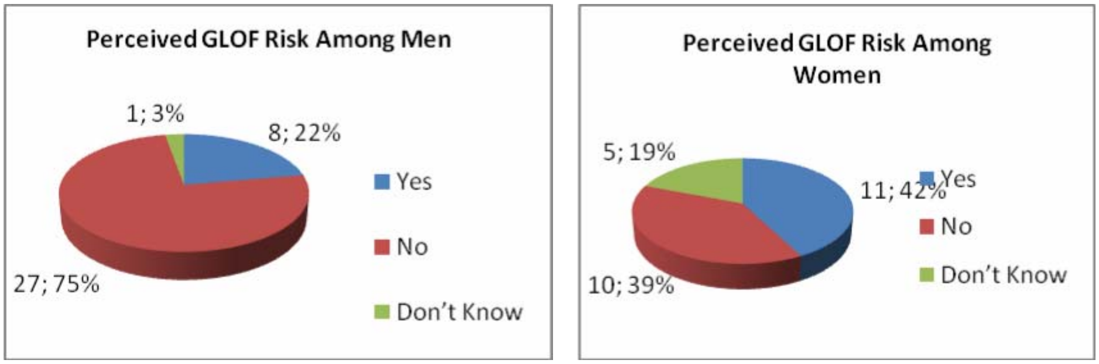

Figure 4-3. Gender difference in risk perception.

Interview results of the present study (Figure 4-3) corroborate the studies that conclude women possess higher sensitivity to the hazard threat than do men. More women (42%) said they were afraid of an impending GLOF event, while only a few (22%) male respondents said they perceived a GLOF risk. Although it is difficult to enumerate the factors contributing to heightened risk perception among women, a few explanations might be appropriate.

First, these riverside communities are patriarchal, conservative, traditional societies where almost all the household decisions and out-of-home activities are under men's control. Women are the sole nurturers and care takers in the family. They are more worried about the matters related to health and safety not only of themselves, but also of other family members (Gustafsod, 1998). This concern is reflected in environmental hazards too. Second, women's heightened sensitivity to risk can be explained based on their sociopolitical status. People who are involved in political affairs have more concern about development, economic, and national defense issues rather than environmental ones (Flynn *et. al.*, 1994). In these communities, women are less involved in political and social activities. This is why men care less about the risk of environmental hazards. Third, men's shallow attention to the risk of environmental hazards can be explained based on what is called the 'economic salience hypothesis'

(Gustafsod, 1998). Men are the major bread-winner of the families in these communities. Men have higher concern about economic rather than environmental problems. Additionally, men have travelled more than their wives, who are often involved in house-keeping activities and working on the farm. Men normally have faced many more risks, which makes them perceive the GLOF risk as a minor one. For men, there are many other topics that are of greater importance. Moreover, men who are more engaged in adventurous tasks, such as hunting, mountaineering, fishing, rowing, and gambling, are bolder. They have a tendency to present themselves as courageous. Therefore, they are likely to dismiss the risk.

4.5 Migrants and Risk Perception

Out-migration has been an old and universal response to hazards and disasters. Many disaster victims leave the devastated place and go to other places, seeking safety and opportunites (Brook, 2003; Mileti, 1999; Wisner *et. al.*, 2004). Disasters in rural areas cause migration of many people to urban areas (Lewis, 1999; Mitchell, 1999). On the other hand, some researchers such as Paul (2005) have argued that out-migration does not always occur owing to hazards and disasters.

My findings uphold the latter view. Instead of emigrating, many new people have moved into the GLOF hazard zone. Thirty-seven (60%, N=62) respondents in my study (Figure 4-4) said they were migrants to the narrow river valleys during the last 20 years *i.e.* after the identification of the Tsho Rolpa hazard. Although my interviews do not provide any concrete information on how many people emigrated from the area during the same period, inferences can be made based on the observations and informal talks with people. In a conversation, a local teacher from nearby Simi Gaun said that members of about half a dozen households from Beding have started living in Kathmandu. But it is hard to say if they emigrated because of the GLOF hazard.

Sacherer (2006) argues that the migration of these Rolwaling Sherpas must be due to their effort to seek good education and health services for their children rather than the perception of GLOF hazard. But in all other villages, the number of people migrating in is greater than the number of people migrating out.

My findings suggest that people who migrated to the riverside villages have heightened risk perception. As shown in Figures 4-5 and 4-6, 41% of the immigrated respondents said that they recognized the GLOF hazard, while only 15 percent of the respondents who were born there said they were afraid of the GLOF risk.

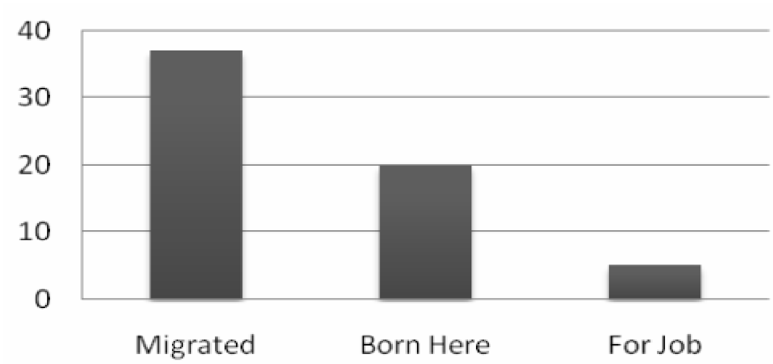

Figure 4-4. Respondents based on the information whether they were immigrants, inborn or staying in the riverine villages for job.

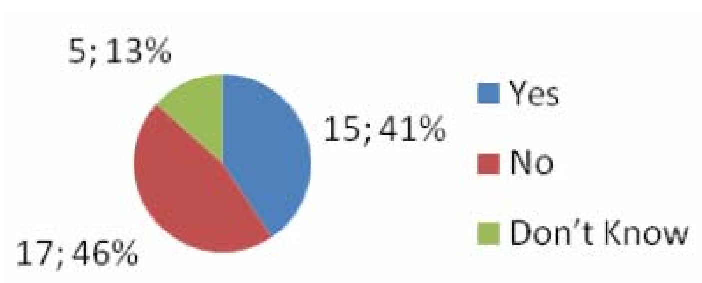

Figure 4-5. Answers by the in-migrant respondents to the question, 'Do you perceive risk of Tsho Rolpa GLOF?'

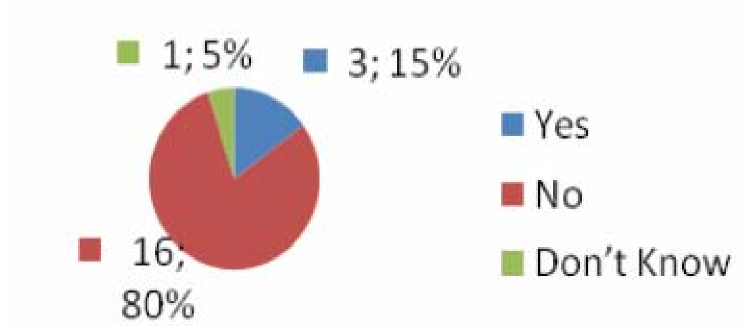

Figure 4-6. Responses of the inborn people to the question, 'Do you perceive risk of or are you afraid of Tsho Rolpa GLOF?'

4.6 Evacuation Behavior and Risk Perception

In summer, 1997, people living in the risk zone were warned of an impending outburst based on the expert assessment of the Tsho Rolpa hazard. They were asked to evacuate. The local district administration deployed policemen in order to force the people to move to a safe place, although it was said to be voluntary. Since the government had not provided any specific place for the people to go to, and leaving their property in the name of taking shelter would not be a wise decision, many people showed reluctance. Most of them moved to safe places despite their unwillingness, but some, mainly elderly members, insisted on staying in their houses. Out of the 62 respondents, 38 (61%) said that they had been living in the riverside villages for more than 10 years, *i.e.* since before the 1997 evacuation. Of these 38 respondents, 28 (74%) said that they evacuated for at least one month, and 10 (26%) said they did not leave their houses. When asked if they were now afraid of the Tsho Rolpa outburst flood any time in future, 10 persons (36%) who had moved to safe place said that they were afraid, *i.e.*, perceived the GLOF risk. Of the respondents who did not evacuate, no one said 'Yes' to the question (Figures 4-7, and 4-8), *i.e.*, no one perceived the risk. They stated that they had neither any fear of a GLOF event nor belief about the 'rumor' of a Tsho

Rolpa outburst. A man from Singati boastingly explained why he was right in saying ‘No’ to my question about the risk perception:

> “I have been living here for more than 50 years now. No such flood has come. I don’t believe such a lake made by God will break. Even if it breaks out, the flood will not big enough to cause any harm to us. At that time also, I was not afraid. So, I and my family did not leave our house. Many people, even police, came to persuade me, but I did not pay any attention to them. You know, who was right!”

Thus, the failure of the lake-burst prediction in 1997 encouraged the disobeyers of the evacuation alerts to think that they have no fear of a Tsho Rolpa outburst in the future as well. They dismissed the risk in order to prove that they were right about their decisions not to evacuate at that time. They invariably stated that there was no room for any one, not only them, to be afraid of the Tsho Rolpa hazard now.

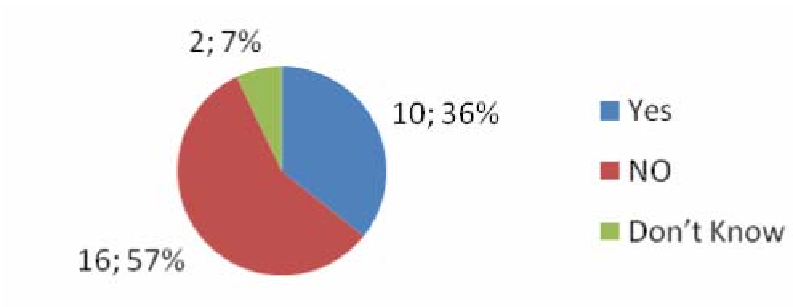

Figure 4-7. Evacuation behavior and risk perception of the respondents.

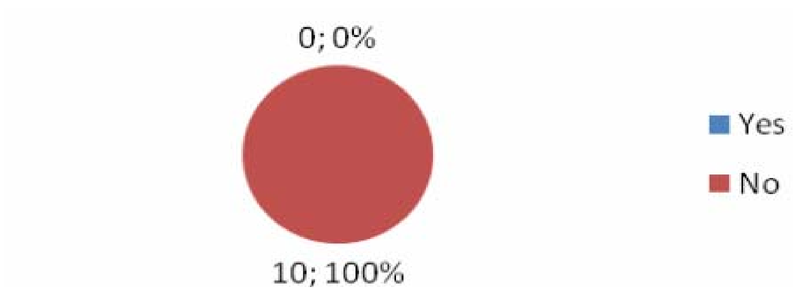

Figure 4-8. Evacuation behavior in 1997 and risk perception of the respondents.

4.7 Risk Perception of Those Who had Been to Tsho Rolpa

Of the 62 interviewees, 24 (39%) said that they had been to Tsho Rolpa at some point in their life. My aim was to know if the persons, who had personally seen the condition and location of the lake, and had had firsthand information on the morphology of the river valley upstream from their villages, would more accurately perceive the GLOF threat. Contrary to my expectation, only 4 (17%) of those who had visited Tsho Rolpa said that they felt the risk of an outburst flood (Table 4-3). Nineteen (79%) of them said that they were not afraid of a Tsho Rolpa outbreak. In constrast, 38 respondents (61%) said that they had not been Tsho Rolpa. Of those, only 18 (47%) said 'No' to the question about risk of the lake-burst. Thus, a high majority of those who visited Tsho Rolpa denied any fear of an outburst flood from the lake.

Have you been to Tsho Rolpa?	Respondents to say 'Yes' to the question, "Are you afraid of Tsho Rolpa GLOF?"	Respondents to say 'No' to the question, "Are you afraid of Tsho Rolpa GLOF?"	Respondents who said 'Don't know' to the question, "Are you afraid of Tsho Rolpa GLOF?"	Total Number of Respondents
Yes	4 (17% of those who said 'yes')	19 (79%)	1 (4%)	24 (39%)
No	15 (40% of those who said 'no')	18 (47%)	5 (13%)	38 (61%)

Table 4-3. Perceived risk by those who have been to Tsho Rolpa and those who have not been.

They narrated their own reasoning and expressed unique opinions about the improbability of dam-breach, and about their safety. A man in his early forties from Jagat, who has been to many tourist destinations of Nepal including different mountain peaks in the course of his job as a trekking guide and helper, explained why he does not have a sense of risk from Tsho Rolpa.

> I have seen glaciers and other glacial lakes also. These lakes must have been there for years. Some lakes are formed and others disappear. This is a continuous process, and such things happen in nature. Tsho Rolpa is also like that. It was there a long time ago, and will be like that for long. Other lakes have not breached, then why Tsho Rolpa alone should? I don't see any probability of a dam-break.

Another respondent from Singati who has visited the Tsho Rolpa Lake three times even claimed that the lake would become extinct, instead. He explains why he does not see any fear of Tsho Rolpa outburst flood in a unique, even bizzare way:

> “I think you also have heard or read about the Fewa Lake of Pokhara becoming narrower and shallower. In the same way, Tsho Rolpa is getting smaller. One day it is likely to disappear. You know why? The glacier brings rocks and snow into the lake. The rock deposits at the bottom of the lake. Debris materials from side walls of the lake also fall into the lake and settle at the bottom. As a result, the level of lake bottom grows up.The lake becomes shallower. The amount of water in the lake decreases, and the force of water to the lake wall will be decreased. The whole lake might dry up one day. Then, why should any probability of an outburst exist there?”

This individual perception seems to be radical at a time when scientific studies have shown that the lake has expanded in both size and volume. They say the lake still poses a danger of outbreak (see Sub-section 5.2.1). For some other respondents, the dam wall is so strong that there is no need to worry about the dam-failure. A hotelier from Singati who visited Tsho Rolpa twice before said:

> The lake is nature-made. It’s not merely like a reservoir of electricity generating project, in which water is held by a cemented wall. This lake is walled by a big hill. It’s in between two big mountains, and dammed by a strong hill-like structure. The moraine-wall is wide. The width can be guessed by looking at the length of the channel constructed at the narrowest place. I think it was a baseless airy matter spread by some people who wanted to make easier money.

For some others, the low risk perception is the result of their theological values and belief systems. A middle-aged woman from Gongar who visited Tsho Rolpa enroute a pilgrammage to Dudhkunda and Panch Pokhari (other glacier lakes) said:

> I don’t believe Tsho Rolpa will break. This is at the sacred place nearby Gaurishankar mountain, the abode of God Shankar (another name for Lord Shiva). Also this is the pool where deities play for fun. So, by god’s grace, nothing will happen to the lake.

Obviously, all of these perceptions are in contrast to scientific findings and beliefs. They say the dam wall is strong while looking from outside. The scientific finding is that the end moraine-wall has been made of big ice slabs which are likely to melt due to increasing temperature. The people believe the lake might become shallower, while expert assessment claims a significant increase in lake volume. The public think the god takes care of the lake, while it is widely argued that human-caused global warming has resulted in a number of potentially dangerous glacial lakes. Thus, there is a distinct communication gap between expert knowledge and people's mental models.

4.8 Risk Perception by Caste

There is no uniformity in the definition of caste (Jati) and classification of castes in Nepal. The most common classification is based on the four-fold Hindu class-division (or Varnas). These four broader caste classes are Brahmins (priestly and learned people), Kshetris (ruling people), Vaisyas (traders, businessmen), and Sudras (laborers, farmers, artists, musicians). These castes constitute a hierarchy, with Brahmins being on top. Muluki Ain (The National Legal Code of 1853) divides the Nepalese people into three main castes: Tagadhari (Brahmins and Kshetris); Matwali (Sherpas, Limbu and a majority of Nepal's other sub-castes); and Pani Nachalne (Untouchables). Although the caste system and discrimination based on castes was outlawed in Nepal's 1962 constitution, it still exists socially in different forms (Rotto, 1997). For convenience, I have classified the interview respondents under four castes: Tagadharis (Brahmins and Kshetris), Newars, Matwalis, and Dalits. Since most of the social and cultural characteristics of Brahmins and Kshetris are similar, it is appropriate to see them as a single caste group. Matwalis are mainly Sherpas, Gurungs, Magars, and Tamangs. Dalits in a common sense are former untouchables (nobody, by the law, is untouchable these days).

Although I had hypothesized that risk perception would be influenced by the caste which a person belongs to, my results show that there is no conspicuous variation on GLOF hazard understanding by caste. Of the total sample population (N=62), 29 respondents were Brahmins and Kshetris, 8 were Newars, 20 were Matwalis, and 5 were Dalits (Table 4-4). Matwalis are believed to be more adventurous and risk taking people based on their occupation and other activities. Sherpas, for example, are widely known to be good trekkers and summit climbers. Yet risk perception is more or less the same for all of these caste groups. Fifty-nine percent of Brahmins and Kshetries, 50 percent of Newars, 65 percent of Matwalis, and 60 percent of Dalits deny that they are living in a GLOF risk zone.

Risk Perception of Respondents by Caste	**Bahuns (Brahmins) and Kshetris**	**Newars**	**Matwalis (Sherpas, Magars, Tamangs etc)**	**Dalits (Former Untouch ables)**	**Total No. of Respondents by Answers**
'Yes'	10 (34%)	3 (37%)	4 (20%)	2 (40%)	19 (30%)
'No'	17 (59%)	4 (50%)	13 (65%)	3 (60%)	37 (60%)
'Don't Know'	2 (7%)	1 (13%)	3 (15%)	0 (0%)	6 (10%)
Total No. of Respondents	29 (47%)	8 (13%)	20 (32%)	5 (8%)	62 (100%)

Table 4-4. Interviewees by castes and their responses to the question "Are you afraid of Tsho Rolpa outburst flood (perceived risk)?"

4.9 Risk Perception and Awareness of Adjustments

The theoretical assumption of the behavioral approach in natural hazard research is that the adoption of adjustments is directly proportional to risk perception (Burton *et. al.*, 1968; Burton *et. al.*, 1993; Kates, 1962; Mileti, 1980). The present study upholds this premise. Only 36 respondents (58%) suggested any preventative and mitigation adjustments they would consider regarding the GLOF hazard (Question No. 20 and 21 in Appendix A). Another 26 (42%) just said 'I Don't Know' in response to the questions. Those who replied to the question named only a few of many possible adjustments to the hazard.

Burton *et al.* (1968) proposed a theoretical range of adjustments to natural hazards and classified them into six broad types. These are the adjustments that a) affect the cause, b) modify the hazard, c) modify loss potential, d) spread the losses, e) plan for losses, and f) bear losses. Most of the responses in my interviews concentrated on category (b), as shown in Table 4-5.

Expressed preventative and protective measures	Make levees and defense walls at riversides	Reduce the water level of lake	Emergency evacuation (running to safe place)	Shift the bazaar and residence to safe place	Prohibit the construction of new buildings etc near the river
Number of respondents	15	8	6	5	2
Percentage (%)	42	22	17	14	5

Table 4-5. Adjustment awareness of the respondents. The adjustments are the tentative answers of the interviewees to the question, "What should be done to prevent the hazard or protect from it?"

The suggested measures of making defense walls at the river side, shifting to a safe place, and controlling land-use or land development are under the broad category of 'modify the hazard.' To reduce water level is to affect the cause of the hazard, and emergency escape to safety and evacuation are adjustments that modify loss potential. These suggested adjustments are demanding in nature. Implementation is not always possible at the individual level; they need to be carried out at the public or government level. But no respondents identified any measurement to be adopted at the individual level. Likewise, nobody mentioned loss-sharing strategies such as flood insurance or cause-affecting measures such as stopping global warming. This indicates that the local people have a low awareness about the range of possible adjustment choices.

From the field observations, it is clear that the people have not adopted any adjustments at the individual level. The villages do not have emergency preparedness. Neither do they have any evacuation plans. They do not talk about what best could be done to receive a warning of flooding at a time when the sirens have been uninstalled. Almost all of them know that there were sirens (early warning system), but nobody seems to call for restoration of the sirens. This all shows that both the risk perception and adjustment awareness is low among the riverine populations of the Rolwaling and Tamakoshi valleys.

4.10 Discussion on the Findings of Informal Coversations and Field Observations

Information obtained from the field observations also backs up the findings of interviews that people in the Rolwaling and Tamakoshi river valleys have a low risk perception of GLOF. The main bazaar in Manthali was shifted from its original location at the floodplain of Tamakoshi to an elevated place at the nearby hill-bottom. It was the effect of media hype and communication in the years 1997 and 1998. The land price in the old Manthali bazaar also substantially decreased. But after a gap of about 8 to 9 years, when there was not much publicity about the Tsho Rolpa lake-burst flooding, the price slowly rebounded. In 2007 it was about double the price of some 10 years earlier. Construction of new houses had been stopped in the floodplain. But now, people have started erecting houses, being once again indifferent to the hazard. This all suggests that the GLOF hazard has no effect on people. Their perception of risk is low. This trend can be observed in Singati, too. Land has become more expensive and people are moving toward the river bank to build houses.

Another major impetus for people’s increased movement toward more unsafe locations in the river valleys is the launching of the ambitious 309 MW hydro-electric project at upper Tamakoshi. The ongoing construction of a road from Singati to Gongar offers further impetus. This has enhanced development of the area. So, there is a tendency on the part of local people not to leave the place. On the other hand, it is natural for people from other parts of the district to come to these villages for employment and economic opportunities. The hydro-project was launched after necessary study of the local geomorphology, environment and the probable effects of

GLOF events was conducted. This has led the people to think that there is no GLOF risk because even the hydro-project is being established. This has provided people with an excuse to justify their denial of the GLOF risk, thereby heightening their vulnerability to future floods.

Chapter 5: Significance and Recommendations

5.1 Significance and Implications

The present study is a place-based and hazard-specific research. It has presented the empirical findings of a field work, without attempting to develop any theoretical framework or model. It provides little concrete guidance on how the risk and hazard perceptions of people are related to the actual adjustment choices and behavior of people at the time of disaster event. Yet, this research is significant in that it has both policy and research implications.

A clear gap exists in perception research on glacial lake outburst floods. No work has focused on public perception of lake-burst flood hazard, let alone on risk perception of the Tsho Rolpa GLOF. This study attempts to fill the void by examining people's hazard awareness and risk perception of GLOF in the Rolwaling and Tamakoshi river valleys of Nepal. At a time when overall emphasis has shifted from the technology-based structural adjustments tradition to the functional adjustments approach in hazards research (Mileti, 1999), importance is given to the study of social aspects of hazard. Natural hazards are viewed as socially constructed, rather than just as the result of a freak nature (Wisner *et. al.*, 2004). My research has adopted a social science perspective to study the problem of the GLOF hazard.

Among the limitations of the study are the low number of respondents and the lack of a truly representative sample. Yet, the findings are significant because this is the first research work to explore people's perception of GLOF. Even a preliminary or pilot investigation such as this can provide valuable insight into the social aspects of the problem. The present study has shown that major findings of hazard perception research conducted in developed countries and on other hazards are applicable to the Himalayas and to the outburst flood hazard. Furthermore, the findings provide baseline information on people's perspectives and opinions which can be utilized at least in two ways: a) to design and launch effective outreach programs and develop disaster emergency management plans in the riverine communities, and b) to make comparative studies by future researchers. The findings can also be used as secondary data by local leaders, government authorities, NGO workers, policy makers, and researchers.

The study has implications for future research as well. Studies are needed of the risk perception of people living downstream from other potentially dangerous glacier lakes such as Imja Glacier Lake of Nepal. The patterns of results could be analyzed to see if the findings complement those of the present study. Any such future study should use comprehensive surveys or interviews based on random sampling of all populations living in GLOF hazard zones. The study results reveal that although the majority of people do not perceive a Tsho Rolpa GLOF risk, a sizable minority of respondents were sensitive to the threat of outburst flood. Yet, the interviews and field observations confirm that no one has adopted adjustments at the individual level. Risk perception is said to be positively related to the adoption of adjustments (Mileti, 1980). A question for future research is: what else besides risk perception influences the adoption of adjustments and protective behavior of people? Probing into vulnerabilities of the riverine communities to GLOF and other hazards is another topic for future research. Vulnerability of communities is increasing due to socioeconomic factors and unsafe built environments. Understanding the determinants of people's vulnerability would help frame effective hazard mitigation polices and, in the long run, conceivably, lead to the adoption of appropriate adjustments.

The present study also offers some recommendations for policy-makers, donor agencies, NGO workers, and local people.

5.2 Recommendations

The findings show that only a minority of residents are worried about the Tsho Rolpa GLOF hazard. The majority of respondents have a low level of risk perception. Although people's perceived risk is more meaningful and comprehensive than assessed risk (Burton *et. al.*, 1968), their belief about hazard might not always be accurate. An example of this is provided by the Nevado Del Ruiz volcanic explosion that killed some 23,000 people of Armero, Colombia, in 1985. People did not take the risk of eruption seriously. The citizens of the town were calm; the mayor was offering reassuring words through radio; and the local priest was placating people over loudspeakers, even after the volcano had already started erupting (Mileti, 1991). Scientists' assessments and predictions fail as well. In 1902, a local newspaper and a report of scientific commission declared on May 7 that the precursory volcanic activities were normal and the town of St. Pierre was perfectly safe, but Mt. Pelee of Martinique erupted on May 8 and the ensuing pyroclastic flows killed about 29,000 people of the town, leaving only two survivors (Martinique, 2007). Tsho Rolpa provides another example of experts' failure to assess the hazard and predict the occurrence of a catastrophic event. Local riparian villagers think that the prediction of lake outburst and issuance of evacuation alerts in summer of 1997 was unfounded and rash. Yet, the people can't claim that the expert assessment was totally misleading. In fact, those involved in the risk assessment claim that the lake is still potentially dangerous. The people's perception of risk might not be fully accurate. Assuming this is the case with the Tsho Rolpa outburst flood hazard, I propose some policy and behavioral recommendations based on the results and discussion presented in Chapter 4.

5.2.1 Recommendation 1: Need for Sound Communication

- *Technical information and findings must be disseminated through local newspapers, radios and TV channels. Different sorts of outreach programs should be launched by the government and development agencies.*
- *Experts must try to understand the people's perceptions, and try to find out the bases of those perceptions.*

A common premise in the perception literature is that expert (professional) opinions about a certain hazard or risk are different from lay beliefs and perception (Burton *et. al.*, 1968). Communication plays a crucial role in bridging these two sides, which often hold contrary ideas (Fischhoff *et. al.*, 1993). In the case of the Tsho Rolpa GLOF problem, there is a distinct communication gap between these two groups. Experts involved in measurement and assessment of the GLOF hazard, as well as the media, say that Tsho Rolpa is still potentially risky to the downstream communities. Various scientific studies have pointed out the need to carry out further mitigation works in order to eliminate the threat of an outburst flood from the glacial lake. The water volume of the lake has substantially increased in the last two decades, leading to a probable outburst (Sakai *et. al.*, 2000; Chikita, 2004). The moraine wall, which consists of two big buried ice cliffs/slabs with several expanding sink holes due to ice-melt, is structurally deteriorating (Reynolds, 1998; Reynolds, 1999). The melting of these ice cliffs, seepage through the loose moraine rocks or fractures of these slabs, and erosion on the distal side of the wall is increasing with time, and will ultimately lead to dam failure (Richardson and Reynolds, 2000). Referring to the inadequacy of the completed mitigation project that constructed an artificial spillway, Kattelmann says, “This 700 meters long spillway lowers the lake level by three meters, at a rate of 6 m3/s. Lowering the lake level by at least 10 meters and possibly 20 meters is thought to be necessary to reduce the risk of an outburst flood to a modest level (2003: p. 150). Based on field observations, a visualized BBC report says that the moraine which is holding the lake in place beneath the boulders consists of ice liable to melt, making it more unstable (BBC, 2002). Other media variously described it as a ‘time bomb’ likely to wreak future damage. Karma Sherpa from Beding, the Tsho Rolpa Station Observer whose job is to monitor the water level and weather patterns and get information to the DHM, said in a TV interview that the lake was becoming longer by about 100 meters every year. “The channel removes 17% of the lake water and relieves the pressure on dam. But it will not make the lake permanently safe. The next phase should be to lower the lake level by a further 15 meters,” says John Reynolds, chief technical advisor to Nepal Government and leader of an expert team on Tsho Rolpa GLOF hazard assessment and mitigation (Pearce, 2000).

Thus, the expert community and media confirm the risk of Tsho Rolpa GLOF. On the other hand, the present study reveals that most lay people do not perceive Tsho Rolpa as a source of risk. This points to a communication gap between experts and residents (also see Section 4.7). Local people do not have access to the findings of expert assessment. For example, technical studies claim that the moraine dam consists of buried ice and is very unstable while local people who have visited the lake say that it is dammed by a strong hill structure. Experts and professional people think that the local people are too ignorant to understand technical aspects of the problem, and local people think that technical assessment is unreliable. People think that the experts also are not very accurate and more knowledgeable when faced by uncertainty.

This gap in understanding and communication must be bridged. One of the best ways to this end might be the effective use of mass media. Technical information and findings should be disseminated through local newspapers, radio and TV channels. Different sorts of outreach programs should be launched by the government and development agencies.

The communication must not be one-way. Experts also must try to understand the people's perceptions, and try to find out the bases of those perceptions. The expert community must also be careful to consider all probable social repercussions of their actions before reaching decisions about warnings and evacuation. For example, the rash decision to issue alerts for evacuation in 1997 spread panic among the people and resulted in socio-economic disruptions. People suffered for no reason.

5.2.2 Recommendation 2: Empowerment of Local People

- *Elements of the structuralist view must be embraced while formulating hazard mitigation and development policies in the area: empower the local people, prevent them from being marginalized, reduce economic disparities, and alleviate poverty.*

The conditions of the Tsho Rolpa hazard and the downstream reverine communities are representative of underdevelopment and marginalization in the Least Developed Countries (LDCs). Disasters, particularly in the LDCs, are attributed to the causes rooted in socio-economic structuring – poverty, marginalization, global economy that enhances economic dependency, and underdevelopment – rather than to the power of natural extremes (Wisner *et. al.*, 2004). This is the structuralist perspective (see Subsection 2.1.3.2. Explaining what hazard mitigation strategies are proposed by this view, Smith says:

> It is a radical interpretation of disaster which envisages solutions based on the redistribution of wealth and power in society to provide access to resources rather than on the application of science and technology to control nature (2001: pp. 50-51).

Smith's explanation accurately describes the condition of my study sites. The villagers are neither too ignorant nor irrational to be blamed. Almost all of the respondents have hazard awareness although some of them underestimate the risk of the hazard and their vulnerabilities for various reasons (Chapter 4). They have no other choice but to continue living there. For example, three families at Chheched have moved very close to the river channel to settle. Previously, they had been living in an uphill village in the lands of certain landlords. When they were freed from particular bonds with the landlords, the riverside was the only place they could settle in because it was under nobody's ownership. They were in no position to pay for lands in a safer place and the government would not provide any place for them, either. Thus, impoverishment attributed to the social practices of the place has made them vulnerable not only to a GLOF event but also to rain-induced flooding.

As the roots of the problem are structural, both politico-economic and social solutions must be sought at a higher level, *i.e.* at societal, national and even international levels. It is recommended that the government and donor agencies such as the World Bank and NIDA, which are major providers of funds necessary for the GLOF mitigation efforts, embrace the essence of the structuralist view while formulating hazard mitigation and development policies in the area. The GLOF hazard mitigation efforts should aim at empowering the local populations and preventing them from being marginalized.

5.2.3 Recommendation 3: Adoption of Sustainable Hazard Mitigation

- *Hazard mitigation plans for the riverine villages must be developed utilizing sound collaboration among local people, the expert community, and government agencies.*
- *Participatory, bottom-up approach to decision making must be adopted.*
- *Emphasis must be placed on the use of functional adjustments.*
- *Sustainable hazard mitigation strategies are useful in the context of global warming.*
- *Local people must bear responsibility for adopting protective measures.*

A sustainability perspective in hazard mitigation (Sub-section 2.1.3.3) maintains that people empower themselves while living with hazards by cushioning their vulnerabilities and enhancing resiliency (Mileti, 1999; Wong and Zhao, 2001). In order for the riverine communities to be adaptive and resilient, sustainable GLOF hazard management plans must be devised at local the level. Since sustainable hazard mitigation emphasizes equitable involvement of local people in development and hazard decisions (Berke, 1995), public participation should be encouraged. It is recommended that such hazard mitigation plans for the riverine villages be developed utilizing sound collaboration among local people, the expert community, and government agencies. Whatever mitigation efforts were made in the past, they were made without the involvement of local people. For example, most of the people did not even know about the decisions to install an early warning system and implement the project of drainage construction at the lake. They knew only after the decisions were being implemented.

This GLOF mitigation effort utilized the traditionally practiced top-down approach of decision making. Decisions were made at the national level by the donor and government agencies. Technicians were assigned to assess the hazard. Decisions to install early warning system and to construct drainage at the lake were taken based on expert opinions. Then, the local people were informed through media and pamphlets about the decisions made already. The local administration and police were mobilized to evacuate people. This decision again was made without local people's involvement. This was a typical top-down decision making, which carried undesirable consequences. Therefore, it is essential that a participatory, bottom-up approach must be adopted when making decisions about the mitigation of the GLOF hazard in the future.

Major mitigation adjustments that have been kept in place so far are of the 'technical-fix' type and comprise engineered structures. The common methods of remediation of a GLOF hazard are: preliminary siphoning, construction of a drainage channel, tunneling, or a combination of these strategies (Richardson and Reynolds, 2000). The first two strategies were partially adopted in Tsho Rolpa.

First, maps delineating outburst flood hazard zones and other features such as roads and trails should be prepared and distributed to local people. It would be better if the maps were produced with local people's involvement. Second, the damaged early warning system and sirens should be restored. The people should be made aware of the issuance of warnings, siren signals, and testing of sirens. Third, a preparedness plan should be formulated for every at-risk village that would provide guidance about people's actions at the time of a probable GLOF event. Disaster preparedness committees can be formed at every village. Training and drills should be conducted in order to keep the people updated about what they should do at the time of an event occurrence. Fourth, awareness campaigns targeted at local people must be conducted so that people can be persuaded not to build houses and other structures in flood-prone areas. Fifth, people must be made aware to run up in the elevation, not along the river channel, at the time of a GLOF event. Finally, the concept of flood insurance can be introduced as an effective loss sharing adjustment. However, attention should be paid that it might not be a practical recommendation at a time when even the concept of life or health insurance is far from people's awareness in the riverine communities. Adoption of these nonstructural (functional) adjustments could be useful for the mitigation not only of the GLOF hazard but also of rain-induced flooding.

The concept of sustainable hazard management has become more contextual at the present time, when the occurrence of global warming is hotly debated in scientific and policy-making circles. If it is a certainty, as claimed by various researchers and organizations such as the Intergovernmental Panel on Climate Change (IPCC) and the World Wildlife Fund (WWF), Tsho Rolpa would not be just a lonely lake to pose the hazard of outburst flooding to the riparian communities of the Rolwaling and Tamakoshi river valleys. Other glacial lakes will grow in size and new lakes will be formed in that part of the glaciated Himalayas. In the past, there was Chubung glacial lake which breached in 1991; now there is Tsho Rolpa; and tomorrow there will be other potentially dangerous lakes. Then, questions such as the following would become evident: How many glacial lakes will have to be emptied through the construction of 20-m deep artificial spillways? And would it be wise to attempt such very expensive projects? The best recommended answer to these questions is to adopt sustainable hazard mitigation strategies starting now.

A final recommendation for local people is that they must not be victims of the 'levee effect' and 'dependency syndrome' (Sub-section 4.3.3). They should recognize that the Tsho Rolpa hazard is not only a problem for the government or donor agencies. They must take responsibility for taking protective actions on their own at the local level. The partial remediation works to reduce the hazard should not numb them to remain quiet and not be involved in any preparedness activities.

5.3 Conclusion

Inaccurate perception of risk can lead to tragic events. Volcanic eruptions of Nevado Del Ruiz in 1985 and of Mt. Pelee in 1902 provide the best examples. Dissonance of risk also might lead to tragedy. Harry Truman refused to evacuate from his lodge near Spirit Lake on Mt. St. Helens in 1980; he denied any volcanic risk saying his environment was safe because he saw the volcano stable throughout his life (Tobin and Montz, 1997). He stubbornly insisted that there was no risk, even after the appearance of physical evidence of eruption. His bravado prevented him from heeding the warnings to evacuate from the restricted zone. He became a victim of the eruption on May 18th, 1980 (Smith, 1998). Similarly, great tragedies cannot be averted because of the false and premature warnings. In the case of the Bhopal Disaster, a series of newspaper articles warned the people living around the Union Carbide Plant of the chemical hazard for at least a couple of years (Patel, 1986). These warnings were ignored by the company authorities, dismissed by the local authorities saying they were sensational, and forgotten by the people as the event did not happen within expected time (Eckerman, 2005). As time went on, a few minor accidents occurred in the plant. The warning systems and indicators of the plant issued so many false alarms and were so unreliable that workers started ignoring early signs of trouble (Patel, 1986). The salience of warnings was lost, and ultimately the great disaster happened on December 3, 1984.

This study has shown that people of the Rolwaling and Tamakoshi river valleys downstream from Tsho Rolpa are living in a condition and with perceptions similar to the Mt. St. Helens and Bhopal events. Probing the risk perception of people and their hazard awareness reveals that people are aware of the GLOF hazard, but underestimate the risk. They fail to realize their vulnerability. They operate on the belief that the lake is unlikely to pose any risk because of the completion of Tsho Rolpa Hazard Mitigation Project. People seem to think that the structural mitigation effort put in place has fixed the problem. This numbing effect coupled with cry wolf effect of the 1997 evacuation has, paradoxically, increased the vulnerability of people. People are living fearlessly in an increasingly hazardous zone. Additional people are moving to the area, and some of them have settled even closer to the river channel. More development works, such as a road and an electric hydro-project, are underway. On the other hand, scientists are warning that the lake is not safe enough, despite the remediation works. It is as dangerous as it was a decade ago. Thus, it is likely that an impending GLOF event will be more disastrous than ever thought. My concern is that the mistakes and consequent tragedies of Bhopal and Mt. St. Helens not be repeated in the rural communities of the Himalayas of Nepal.

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Appendix A: Interview Schedule

I. General Information Questions:

1. How long have you been living here (in this valley)?
2. Is this your ancestral village or did some of your parents/grandparents immigrate there?
3. What do you do for your living?
4. (If farmer) How many acres of farmland do you possess? (If cattle keeper) How many cattle/sheep/yaks do you have?
5. Why did you choose to live in the river valley, but not uphill?
6. What do you think are the good and bad aspects of living in the river valley?

II. Questions about GLOF hazard and Risk Perception:

7. When does the Rolwaling/Tamakoshi River flood? Does it flood during the monsoon season only?
8. Have you experienced any big flood in the past?

   Yes: in which year? How many such floods occurred in the last 20 years?

   No: have you heard about the flooding from other older people?
9. What can you tell me about the most recent significant flood?

   Probe: When? Where? How did it affect you/village?
10. What do you think was the cause of the flood?
11. Do you know / have you heard about Tsho Rolpa glacial lake outburst flooding (GLOF)?

    Yes: When and who told you?

No: (The interviewer briefly describes GLOF – a sudden, dramatic flood caused by the failure of Tsho Rolpa).

12. Tell me what happened or what you did at the time of 1997 panic when there was a general warning to evacuate people.
13. Have you been to Tsho Rolpa?
14. Can you tell me something about Tsho Rolpa, e. g. location, size, shape, distance from your place etc. based on what you saw or heard from other people?
15. Do you see any probability of Tsho Rolpa outburst in future?
16. Are you afraid of or do you perceive any risk of Tsho Rolpa GLOF?

III. Questions about Respondent's knowledge on Adjustments:

17. Do you know if there is an early warning system (siren) in your village? Is it working? How much faith do you have on it?
18. Have you heard about the project done at the lake? Is it enough?
19. If you were warned about an impending GLOF and told to evacuate, where would you go?
20. What can be done to prevent the occurrence of GLOF event from Tsho Rolpa?
21. What can be done to reduce the losses if a GLOF event occurs?
22. Whose role do you think will be most important to mitigate the risk of Tsho Rolpa GLOF?
23. Do you know / have you heard about Global Warming?

    Yes: What is it?

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