Disaster Management Community

Solution Exchange Bhutan

Solution Exchange for the Disaster Management Community
Solution Exchange Bhutan
Discussion Summary

GLOF Risk Mitigation - Key Issues, Challenges and Approaches

Compiled by G. Padmanabhan and Sonam Lhaden, Resource Persons, Nupur Arora, Research Associate, and Guest Moderators G. K. Bhat, Krishna Vatsa and Rajeev Issar

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Guest Moderators: G. K. Bhat, TARU, and Krishna Vatsa and Rajeev Issar, UNDP's Bureau for Crisis Prevention and Recovery (BCPR), New Delhi

Posted 5 November 2008

UNDP's Bureau for Crisis Prevention and Recovery (BCPR) in partnership with the European Commission Humanitarian Organisation (ECHO), is presently undertaking a GLOF risk reduction initiative in India, Bhutan, Nepal and Pakistan. The project aims to identify and formulate community-based GLOF risk mitigation and preparedness approaches. To learn more click www.managingclimaterisk.org/glofs.htm.

At present, there is an inadequate understanding of the nature of GLOFs, their physical dimensions and properties as well as the entire cycle of a GLOF disaster. Recognizing this emerging hazard, it is vital to assess the probability of the occurrence of GLOF events and the factors likely to influence them.

Members may also recall the recent discussion on Mitigating Risk of Glacial lake Outburst Flooding (GLOF). Among other key findings, members highlighted on the importance of structural and non structural risk mitigation measures (To view the Consolidated Reply please click: http://www.solutionexchange-un.net.in/drm/cr/cr-se-drm-08050801.pdf, PDF, Size: 114 KB)

In view of the above, we seek members' experiences and views on the key Issues and challenges to GLOF. We request members to specifically discuss;

- **Current and future probability of occurrence of GLOF events in the region and factors that are likely to influence such incidents**
- **Risk Mitigation measures adapted by various countries for GLOF and the common challenges faced**

The discussion will be moderated by a panel comprising of experts from hazard and risk assessment, climate change risk management and disaster management:

- Dr. G. K. Bhat, Senior Scientist and Expert, TARU
- Dr. Krishna Vatsa, Regional Disaster Reduction Advisor, UNDP-BCPR (Bureau for Crisis Prevention and Recovery)
- Rajeev Issar, Team Manager, Regional GLOF Project, UNDP-BCPR (Bureau for Crisis Prevention and Recovery)

A synthesized report encapsulating the key discussion outputs shall be shared with the participants and practitioners. The findings and learning from the e-discussion shall feed into the deliberations of the Regional Workshop on GLOF Risk Mitigation scheduled to be held in December 2008 in Bhutan.

We look forward to your active participation in this e-discussion!

Responses were received, with thanks, from members from CPRP-Net, E&E-Net, DRM Asia Network, Disaster Preparedness Net Nepal, Pamirtimes-Pakistan, Solution Exchange for the Disaster Management Community in India, and Solution Exchange Bhutan:

1. **Ripendra Awal, Kyoto University, Japan**
2. **Sarat Panda, United Nations Development Programme (UNDP), New Delhi, India**
3. **Sampurnananda Mahapatra, GoI-UNDP Disaster Risk Management Programme, New Delhi, India**
4. **Ejaz Karim, Earthquake Reconstruction and Rehabilitation Authority (ERRA), Islamabad, Pakistan (Response 1 , Response 2)**
5. **Karma Rapten, GLOF Regional Project, Bhutan**
6. **Pelzang Wangchuk, Consultant, Thimphu, Bhutan**
7. **Arshad Ashraf, National Agricultural Research Centre, Islamabad, Pakistan**

Further contributions are welcome!

Summary of Responses

The discussion on 'GLOF Risk Mitigation – Key Issues, Challenges and Approaches' received in-depth responses from members. Respondents provided fresh perspectives towards understanding the phenomenon of Glacial Lake Outburst Flooding (GLOF) and the kind of challenges inherent in risk mitigation endeavours, along with providing suggestions for reducing the risk of GLOF.

Members stated that **climatic change** is the principal trigger for the increasing retreat/melting of glaciers and the formation of glacial lakes. They mentioned that after 1960s, the number and frequency of GLOF events has experienced an upward trend as de-glaciation, formation of glacial lakes and their outburst are a direct outcome of climatic change. With this in mind, discussants opined that it would be important to make accurate estimates of the likely magnitude of potential floods. For this, detailed hazard

assessment studies are necessary to identify potentially hazardous basins and to evaluate the likely economic loss and appropriate mitigation activities.

Respondents pointed out that ice avalanches trigger most GLOF events and yet most of the existing models are applicable only to outburst floods caused due to overtopping. Most models treat the water as floodwater flow, though it may also be a sediment or debris flow. Members felt that the models predicting such incidents must incorporate all types of failure modes including overtopping, seepage/piping failure, ice avalanche and overfilling due to higher rates of glacial melt, etc.

Discussants also mentioned that since the Himalayan region is in a very active seismic zone, there is probability of an earthquake triggering a GLOF event. Thus, they felt it is essential to establish linkages with earthquake risk reduction initiatives. At the same time, they recognised the difficulties involved in predicting earthquake induced GLOF events and suggested carrying out micro-seismic zonation to help determine GLOF hazard zones.

Members noted that studies on GLOFs primarily focus on the interpretation of satellite images to identify potentially hazardous lakes. Very few studies have been undertaken to analyze downstream hazards. They suggested taking initiatives to **develop mathematical models** combined with geographic information system (GIS) and Remote Sensing (RS) techniques to identify areas most susceptible to damage. This they felt would help mitigate the impact of GLOF incidents in the future. They also suggested developing an integrated model to predict failure modes, flood routing, identify hazard-prone areas, and evacuation routes. This will enable multi-scenario modelling of moraine dam failures to predict potential flood/sediment flow hazards and risks, and to identify mitigation measures in downstream areas.

Recognizing the limitations of structural mitigation measures, contributors outlined the importance of raising community awareness and adopting a multi-stakeholder risk reduction approach dovetailed with capacity enhancement initiatives, and also highlighted the **need to mainstream community-based approaches** into local development interventions.

Citing an experience from Tsho Rolpa Lake, **Nepal**, members pointed out that although the lake's water was successfully drained using structural methods, this approach is prohibitively expensive in most cases and fraught with challenges. Hence, local knowledge and coping mechanisms must be explored, documented, and incorporated into overall GLOF preparedness and response plans as per the local needs and context. They also advise supplementing these structural measures with proper early warning systems, community preparedness measures, reduced forest fire incidents and enhanced coordination among stakeholders at the national and regional level for knowledge sharing and cross-learning. Overall, they opined that structural interventions are not a very viable solution for reducing the cause as well as the impact of GLOFs.

In addition, respondents voiced concern over the fact that infrastructure development in areas vulnerable to GLOFs continue without factoring in the risk of a GLOF event. Therefore, they supported factoring GLOF risks into the planning of crucial infrastructure project.

Looking at ways **to reduce the risk of GLOF**, respondents listed key activities for national and regional level, including:

- Ensure the definition and understanding of the specific hazard is clear
- Disseminate information on the dynamics/causes of various hazards to communities in an easy-to-understand format
- Assess the hazards and risks through a mapping and analyze the data
- Do a risk classification based on demographic, hazard and exposure profiles and produce risk communication tools for raising awareness, undertaking mitigation measures (including structural and non-structural ones), building capacity, strengthening existing coping mechanisms, and evacuation

- Establish an early warning system incorporating the local approaches and strengthen existing tools like wireless, FM, radio
- Build the capacity of local communities through training on search and rescue, first response, information dissemination, evacuation and relief management as well as for undertaking mitigation measures to reduce risk
- Incorporate local cultural practices in risk mitigation and preparedness approaches
- Involve identified vulnerable communities in risk reduction activities.
- Generating awareness about GLOF hazards among communities and local administrations so that they can take appropriate preparedness and risk mitigation measures well in time.

Discussants also emphasized the need to develop comprehensive **risk reduction measures at national and regional levels** for mitigating GLOF events.

At the same time, respondents stressed the need for appropriate **policy and advocacy interventions** to ensure a strong community level and administrative response to such events.

Discussing the **significant challenges** involved in undertaking the above activities, members noted the:
- Lack of adequate preparedness mechanisms and institutional set-up for risk reduction and hazard mitigation
- Poor resource base of communities and a lack of accessibility and communication
- Huge investment required including the need for sophisticated equipment and data for detailed hazard mapping
- Information gap between science and research institutions, policymakers and communities on GLOF hazards/risks
- Lack of trained professionals and institutional capacity
- Tough terrain and daunting weather conditions, which hamper accessibility
- Over-dependence of communities on the government for risk mitigation and preparedness initiatives
- Lack of community cohesion obstructing effective community-based disaster preparedness/mitigation planning

Participants also referred to the challenges inherent in undertaking comprehensive GLOF risk mitigation measures, and stressed the importance of adopting a comprehensive approach involving communities and local administrations, and ensuring they get the necessary support through appropriate institutional systems and capacity building programmes.

In conclusion, discussants highlighted the dynamic nature of the risks posed by GLOFs, especially to the due the increasing rate of climate change. Hence, conducting hazard assessment studies to estimate the extent and nature of flooding and developing an integrated model would help analyze the downstream hazard.

Some of these issues will be discussed in the second part of the discussion on “Community approaches, EWS and land-use planning practices for GLOF risk mitigation” – and perspectives to help shape suitable interventions will be formulated.

Related Resources

Recommended Documentation

From Ripendra Awal, Kyoto University, Japan

Impact of Climate Change on Himalayan Glaciers and Glacial Lakes

Case Study; by Samjwal Ratna Bajracharya, Pradeep Kumar Mool and Bassanta Raj Shrestha International Centre for Integrated Mountain Development (ICIMOD) and United Nations Environment Programme Regional Office Asia and the Pacific (UNEP/ROAP); Kathamdu, Nepal; June 2007
Available at http://www.roap.unep.org/publications/Impact_Climate_Change.pdf (PDF, Size: 3.91 MB)

Inventory of 9,000 glacial lakes in the Hindu Kush-Himalayan region of which nearly 203 glacial lakes are identified as potentially dangerous

IPCC Third Assessment Report - Climate Change 2001
Report; Intergovernmental Panel on Climate Change; Geneva; 2001
Available at http://www.ipcc.ch/ipccreports/tar/vol4/english/index.htm

Addresses issues such as the extent of human activities influence on global climate, the impacts of changed climate (including GLOFs) on ecological and socio economic systems

An Overview of Glacial Hazards in the Himalayas
Report; by Shaun D. Richardson and John M. Reynolds; Quaternary International, Vol. 65/66; 2000; Permission Required: Yes, paid subscription required
Abstract available at http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VGS-404H2M8-4&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=20a5cc5bacc621eae6586a502b5f9a00

Raises concerns on glaciers' potential hazards in the Himalayas, and in similarly glacierised regions of the world

Disaster Risk Management in a Changing Climate (*from Sampunananda Mahapatra, GoI – UNDP Disaster Risk Management Programme, New Delhi, India)*
Discussion paper; by F. Sperling and F. Szekely; Vulnerability and Adaptation Resource Group; Washington D.C.; 2005
Available at http://www.unisdr.org/eng/risk-reduction/climate-change/docs/DRM-in-a-changing-climate.pdf (PDF, Size 1.88 MB)

Discusses inter-linkages and differences between disaster risk management including floods and adaptation to climate change and outlines opportunities and barriers for collaboration

From Sonam Lhaden, Resource Person

Glacial Lake Outburst, A Real Threat
Article; by Rabi C. Dahal; Bhutan Observer; Thimphu; 31 October 2008
Available at http://www.bhutanobserver.bt/2008/bhutan-news/10/glacial-lake-outburst-a-real-threat.html

Highlights that one of the seven potentially dangerous glacial lakes (one of the sources of the Mangdechhu River) holds high potential for glacial lake outburst flooding (GLOF) in the future

Monitoring Climate Change
Article; by Sonam Rinchen; Bhutan Observer; Thimphu; 16 September 2008
Available at http://www.bhutanobserver.bt/2008/featured-stories/09/monitoring-climate-change.html

Article on glaciers and glacial lakes in Bhutan which are potentially dangerous due to GLOF

Recommended Organizations and Programmes

From Ripendra Awal, Kyoto University, Japan

United Nations Environment Programme Regional Office Asia and the Pacific (UNEP/ROAP), Thailand
2nd Floor, United Nations Building, Rajdamnern Nok Avenue Bangkok 10200, Thailand; Tel: 662-288-1870-4; Fax: 662-280-3829; http://www.roap.unep.org/index.cfm

Works with governments and local authorities to develop and implement cleaner and safer policies and strategies for reducing GLOF risk

Intergovernmental Panel on Climate Change, Switzerland
C/O World Meteorological Organization, 7bis Avenue de la Paix , C.P. 2300, CH- 1211 Geneva 2, Switzerland; Tel: 41-22-730-8208/4; Fax: 41-22-730-8025/13; http://www.ipcc.ch/about/index.htm

Provides decision-makers and others interested information about climate change and talks about floods

International Centre for Integrated Mountain Development (ICIMOD), Nepal
G.P.O. Box 3226, Khumaltar, Kathmandu, Nepal; Tel: 977-1-5003222; Fax: 977-1-5003299/77; http://www.icimod.org/?page=abt

Knowledge development and learning centre serving the countries of the Hindu Kush-Himalayas to assist these to understand climate change and glacial floods.

UNDP and Bureau of Crisis Prevention and Recovery, United States
One United Nations Plaza, DC1-20th Floor, New York, NY 10017 USA; Tel: 1-212-906-6175; http://www.undp.org/cpr/we_do/integrating_risk.shtml

Works around the world to restore the quality of life for men, women and children who have been devastated by natural disaster including floods

From Karma Rapten, GLOF Regional Project Bhutan, UNDP Bhutan, Thimphu

The Netherlands Climate Assistance Programme, The Netherlands
ETC International, P.O. Box 64, 3830 AB Leusden, The Netherlands; Tel: 31-0-33-432-6000; Fax: 31-0-33 494-0791; http://www.nlcap.net/about/background/

Created to address the problem of climate change including floods by assisting developing countries to become self -supporting in formulating climate policy

European Commission's Humanitarian Aid Department (ECHO), United Kingdom
Practical Action, The Schumacher Centre for Technology & Development, Bourton on Dunsmore, RUGBY, CV 23 9QZ, United Kingdom; Tel: 44-1926-634403; Fax: 1926-634405;
http://practicalaction.org/?id=climatechange_adaptation

Targets vulnerable communities living in the main disaster-prone regions of the world

Department of Geology and Mines, Bhutan *(from Pelzang Wangchuk, Consultant, Thimphu)*
P.O. Box 173, Thimphu Bhutan; Tel: 00975-2-323096/322879/323349; Fax: 00975-2-323013/326134/324193; gsbmti@druknet.bt; http://www.mti.gov.bt/dgm/dgm.htm;
http://www.mti.gov.bt/dgm/DGM-UNDPGEF/main.html

Department does various studies related to landslides, neotectonics, seismicity, and other geo-hazards, including GLOF

Related Consolidated Replies

Mitigating Risk of Glacial Lake Outburst Flooding, from Rajeev Issar and Rahul Pandit, Regional GLOF Risk Reduction Initiative, UNDP's Bureau for Crisis Prevention and Recovery (BCPR), New Delhi (Experiences; Examples). Disaster Management Community, Solution Exchange India and Solution Exchange Bhutan, Issued 31 May 2008
Available at http://www.solutionexchange-un.net.in/drm/cr-public/cr-se-drm-08050801-public.pdf (PDF, Size: 114 KB)

Shares a wide range of research studies on GLOF and information the affects of outburst flooding on communities and listed mitigation measures to reduce impact

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Responses in Full

Ripendra Awal, Kyoto University, Japan

have attached brief overview of "Challenges and approaches towards GLOF risk mitigation" in terms of mathematical modeling of flooding and risk management for the first thematic area (Key issues, challenges and approaches towards GLOF risk mitigation).

Challenges and approaches towards GLOF risk mitigation

Among many natural dams, the failure of moraine dam is most dangerous. The formation and failure of these dams and lakes are linked with different triggering factors, i.e. earthquake, heavy precipitation and snow melting etc. Global climate change is accelerating the triggering factors like snow melting and increasing frequency and magnitude of extreme rainfall. Glacial Lakes Outburst Flood (GLOF) is the one of the main cause of flash flood in the Hindu Kush-Himalayan (Bhutan, Nepal, India, Pakistan, China and Afghanistan) region. Warming trends have already had significant impacts in the Himalayas – most significantly in terms of glacier retreat and significant increases in the size and volume of glacial lakes, making them more prone to GLOF. The frequency and magnitude of moraine dam failures and GLOFs will continue to increase with the current and continued scenario of global warming. Glacial lakes are common in the High Himalayas close to existing glaciers.

A recent inventory of glacial lakes in the Hindu Kush-Himalayan region carried out by ICIMOD has shown that there are 9000 glacial lakes of which nearly 203 glacial lakes are identified as potentially dangerous and much of the settlement and infrastructure along the rivers originating from these lakes is at immediate risk (***Bajracharya et al., 2006***). On the Indian subcontinent, temperatures are predicted to increase between 3.5 and 5.5^{o}C by 2100 (***IPCC, 2001***). Many of the big glaciers melted rapidly and gave birth to a large number of glacial lakes. The trend of GLOF events which occurred in Nepal and in Tibet, but affected the territories of Nepal shows that frequency of GLOF events is increasing after the 1960's decade.

The deglaciation, formation, growth and GLOFs are phenomena closely related to climate change. These events may cause floods of great magnitudes in downstream river reaches which may affect to very great distances from the outburst source and may cause loss of life and properties and sediment disaster in the region. As GLOFs pose severe threats to humans and man-made structures, it is important to make accurate estimates of the likely magnitude of potential floods. Therefore, proper hazard assessment studies must be carried out in potentially problematic basins to evaluate the likely economic loss and the most appropriate method of mitigation activities. However mathematical model to predict such a failure mechanism are still lacking.

Moraine dams generally fail by overtopping and incision. Potentially dangerous lakes typically require a trigger mechanism to initiate a flood. The triggering event is most frequently an ice avalanche from the toe of the retreating glacier which generates waves that overtop the dam. Melting of ice cores and piping are other reported failure mechanisms. More than 61% of GLOFs were initiated by displacement waves from ice avalanches that collapsed into the lakes from hanging or calving glaciers and rock avalanches (***Richardson and Reynolds, 2000***). Most of the existing models are just applicable to overtopping failure mode and resulting flood is treated as a flood water flow. However in actual failure based on geometry and material of the dam the flow may be sediment flow or debris flow. Moraine dams are also susceptible to slope stability failure because they are steep-sided, have relatively low width-to-height ratios, and consist of poorly sorted, loose sediment. Most of the models are not integrated with slope stability in the longitudinal direction. So the model to predict flood/debris flow hydrograph should incorporate all failure modes including overtopping failure, stability, seepage/piping failure and wave overtopping due to ice avalanche and rock fall.

Most of the study on GLOF is focused on interpretation of satellite image to predict the potential hazardous glacial lake and very few studies are focused on analysis of downstream hazard. Prediction of the GLOF induced debris flow and downstream hazard areas are a complex procedure. Numerical model combined with GIS and RS can be used to delimiting the downstream hazardous zones. Both structural

and non-structural measures can be used to reduce the hazards from moraine dam failures and GLOFs. Identification of areas that are most susceptible to potential GLOF events will help to mitigate the hazard of future potential GLOF.

Awareness of the possibility of such an event will allow precautions and hazard mitigation measures to be taken in advance. The development and application of integrated model to predict failure modes of moraine dam, resulting outflow hydrograph, flood routing, prediction/delineation hazard prone area, refuges and evacuation routes in the downstream to evacuate local residents in a safe and proper manner in the event of floods is essential. Such type of model can be used to carry out a multi-scenario modeling of moraine dam failure to predict potential water/sediment hazards, risks and their mitigation in the downstream river reach.

References:

- Bajracharya, S.R, Mool, P.K. and Shrestha, B.R.: The impact of global warming on the glaciers of the Himalaya, Proceedings of International symposium on Geo-disasters, infrastructure management and protection of world heritage sites,pp.231-242, 2000.
- IPCC 2001: IPCC Third Assessment Report – Climate Change 2001. Working Group I: Technical Summary, Geneva, WMO and UNEP.
- Richardson, S.D. and Reynolds, J.M.: An overview of glacial hazards in the Himalayas, Quaternary International, Vol. 65/66, pp. 31-47, 2000.

Sarat Panda, United Nations Development Programme (UNDP), New Delhi, India

I congratulate to the GLOF team members for initiating discussion on such an unfolding natural hazard. It is for sure that the impact of GLOF would be devastating particularly to the communities and assets in the down stream. Several pioneering works have already been initiated, however given the complex nature of this natural phenomena aggravated by Global warming and other human induced actions such as deforestation, conclusive risk reduction measures are yet to be worked out both at the regional and national level.

GLOF and its impact could be tackled / minimized through proactive risk management efforts involving the vulnerable stakeholders. All initial efforts may be made in the direction preparedness and early warning so that the impact GLOF and related incidents could be minimized. Simultaneously, these preparedness efforts must be supplemented by ongoing Hazard mapping and risk assessment through GIS for undertaking mitigation measures both structural and non-structural. This emerging issue, I think would need huge investments. Strong political will and public policy interventions would be required. Policy level advocacy both at the national and regional level backed by strong economic sense would be a must for articulating the need and mobilizing the positive political will and public policy.

Hope, these non-technical /commonsensical ideas would contribute to the forthcoming discussions.

Sampurnananda Mahapatra, Government of India-UNDP Disaster Risk Management Programme, New Delhi, India

A glacial lake outburst flood (GLOF) is created when water dammed by a glacier or a moraine (http://en.wikipedia.org/wiki/Moraines) is released. A water body that is dammed due to blockage of a glacier or moraine is called a marginal lake, and a water body that is capped by a glacier due to balance of geothermal heating and the heat loss at the ice surface is called a sub-glacial lake. Both type of lake may trigger a GLOF in the event of increase of water mass beyond the carrying capacity of basin.

A glacial lake outburst flood (GLOF) can happen due to melting of age old uphill glaciers because of global warming (climate change) or a major land slide or due to earthquake or volcanic eruption or

severe rainfall in uphill side of the glacial mountains. Possibility of glacial melting induced GLOF due to any major forest fire can not also be underestimated. However amongst above, global warming induced glacier melting has caught a serious attention of global community, since innocent tribal people residing in glacial mountains has to bear the brunt of greenhouse gas emission induced global warming. The culprit for greenhouse gas emission is non other than rampant industrialization and consumerism.

Catastrophic failure of the containing ice or glacial sediment can turn into GLOF over a time span of minutes to days. Peak flows as high as 15,000 cubic meters per second have been recorded in these events, suggesting that the v-shaped canyon of a normally small mountain stream could suddenly develop an extremely turbulent and fast-moving torrent some 50 meters deep. On a downstream floodplain, it suggests a somewhat slower inundation spreading as much as 10 kilometers wide. Both scenarios are horrific threats to lives, property and infrastructure.

High Probability in occurrence of GLOF hazards globally due to Climate Change: As we all know, enhanced emission of gases like Carbon Dioxide, Methane, Chlorofluorocarbons etc. due to rapid and over utilization/burning of carbon based exhaustive resources has increased the green house effect (maintenance of tropospheric warmth) that has created a conducive environment for melting of global ice deposits. The consequential effect out of this is melting of mountain glaciers, sea level rise due to melting of polar ice, abnormalities in local weather cycle, extinct of several animal and vegetation species etc. In the present context, it is needless to discuss further the consequential adverse chain effects out of above phenomena.

However, it is noteworthy that melting of glaciers due to climate change can evolve as single most cause of rapid increase in GLOF hazards globally. Addressing the issue of climate change has become a toughest challenge for human societies, since united and coordinated efforts of world community is required to reduce emission of green-house gas to check the world troposphere (lowest layer of earth's atmosphere) from increase in the average measured temperature. Hence, from the perspective angle of climate change issues (global warming), present and future probability of frequency in occurring GLOF hazards are significantly high.

GLOF Disaster Risk Reduction Measures:

Efforts may be given to mitigate GLOF hazards through physical reduction in the flooding risks of glacial lakes. This consists various measures such as draining of dangerous glacial lakes by siphons or pumps, cutting a drainage channel for the lake to periodically drain and flood control measures downstream to reduce the effects of the flood (Rana et al. 2000). A multiple benefit of GLOF mitigation measures may be safe management of the water resource for hydro-electric power at a local scale and for export" (Reynolds and Richardson 1999).

In addition to hydro power, the siphoned water could also be used to supplement dry season flows, maintain adequate water levels in downstream ecosystems to protect valuable fish stocks, supply water for local usage, and even to provide recreational facilities.

Such direct risk reduction measures, however, have their own disadvantages. Pumping is expensive because of the remote location of possible GLOFs at high altitudes. Heavy infrastructure must be flown by helicopter to the site. Further, the construction of a siphon itself might breach the moraine dam and risk triggering a GLOF. These disadvantages notwithstanding, there is one instance in Nepal – the Tsho Rolpa Risk Reduction Project – where such responses have in fact already been implemented in an integrated manner **(Page 21, Disaster Risk Management in a Climate Change, 2005).**

However, an integrated effort of daily monitoring of satellite imageries of glacial lakes and its surroundings, community based early warning & preparedness measures, community participation in checking large scale forest fire and trans-boundary coordination and information sharing among the

neighboring countries connected to any GLOF phenomenon can considerably reduce the risks of GLOF hazards.

Ejaz Karim, Earthquake Reconstruction and Rehabilitation Authority (ERRA), Islamabad, Pakistan *(response 1)*

I am very optimistic that input from such professional expertise will absolutely help to really boost CBDRR. I think in modern DRR initiatives, we are observing a lack of community based mainstreaming in local development interventions. Specifically related to GLOF cases, it is clearly an ignored subject in northern Karakuram, Himalaya and the Hindukush ranges, despite having experienced catastrophic flood events in the past.

Being a resident of Hunza valley, and working on geohazards as a geologist for the past 8 years and having relevant experience in disaster risk management, I am very concerned about the structural recommendations put forward by different experts which are not actually viable solutions to reduce the cause as well as the impact. Therefore, it is obvious to first explore what local knowledge exists, what local coping mechanisms and early warning systems are in place as well as what drills/ exercises have been conducted etc.

It is requested that these aforementioned subjects should be incorporated into overall GLOF preparedness and response plans, according to local needs and context.

Karma Rapten, GLOF Regional Project, Bhutan

A face to face discussion on the GLOF e-Discussion Part 1 - Key Issues, Challenges and Approaches, was held in Bhutan on November 3, 2008 coinciding with the launch of the re-vamped Solution Exchange Bhutan Website. The discussion was attended by various national stakeholders, representatives of NGOs and CBOs and individuals interested in the subject. The discussion was moderated by Mr. Karma Rapten, Project Support Officer for Bhutan.

The results of the discussion will be consolidated and posted on Solution Exchange Bhutan Network and cross-posted on other networks in the next few days.

As proposed, the discussion focused on part 1 of the discussion - **Key issues, Challenges and Approaches towards GLOF Risk Mitigation.** The discussions revolved around the following issues:

- What is the level of awareness at the community and administration level about the likelihood of GLOF events? Is this risk being duly acknowledged?
- How are mountain communities being made aware of the risk of GLOFs?
- How is GLOF risk being addressed in different countries/regions? What are the challenges and constraints?

Results of Discussion

There was overwhelming consensus that the administration and local communities are generally aware of risks posed by GLOFs. However, both the local administration and communities had very little scientific knowledge on GLOFs and associated hazards and risks. The awareness differed from place to place based on personal experiences and memory over time. The level of awareness is also contextual, with people having experienced GLOFs in the past being more aware than those who have not been affected by GLOFs.. However, not much is done to reduce the risks posed by GLOFs to vulnerable population.

In spite of such high levels of awareness, people are continuing to settle or own properties in vulnerable areas. Secondly, the lack of institutional capacity and resources at the community and Dzongkhag levels

to mobilize and assist people to deal with preparedness and mitigation measures has been appreciated as a priority area of intervention. Thirdly, people are reluctant to resettle in other locations due to sentiments attached to their ancestral homes, land and property. In some cases, there is an urgent need to relocate people on a priority basis. For instance, the people of Thanza are only about 20 minutes away from the lake and in the event of a GLOF, they would not have adequate time to respond/evacuate.

It was also observed that the Government is fully aware of the risks posed by GLOFs and its social and economic implications, in particular the Punakha-Wangdue valley, and efforts are underway to address these risks - as indicated by various initiatives currently being implemented in the valley. Current interventions and initiatives in the GLOF shadow valley of Punakha and Wangdue include a GLOF adaptation project implemented through UNDP/GEF financing, and the Regional GLOF Risk Mitigation Project funded through DIPECHO and UNDP/BCPR.

There have also been numerous studies and some mitigation interventions in the past including a vulnerability mapping study conducted by the Department of Geology and Mines through the Netherlands Climate Assistance Programme (NCAP) that covered the entire GLOF shadow valley of Punakha, Wangdue and Dagana Dzongkhags. In addition, at the central level, there have been several initiatives that have addressed disaster management in a holistic manner – including up-gradation of the Disaster Management Division to a Department, adoption of a Disaster Risk Management Framework and Guidelines and awareness activities in schools and communities.

The participants also noted that most risk reduction initiatives in the past have focused mainly on structural measures and communities have received very little attention. It was recognized that community-based response and preparedness measures are important aspects in reducing the risk of GLOFs. It was noted that, while communities are fully aware of the risks posed by GLOFs, they are not capable of responding to risks, due to a lack of scientific knowledge and guidance.

The discussion noted that limiting development in vulnerable areas is not a practical approach and that the establishment of an early warning system was thus indispensable in preparing communities and reducing risks from GLOF hazards. The discussion also noted that predicting/forecasting GLOFs is a difficult task and hence it is pertinent to accord greater attention and focus on community-based awareness and preparedness programmes.

It was noted that, while government agencies fully recognize the risks posed by GLOFs, it continues to establish/construct infrastructure/facilities in vulnerable areas along the valley. This promotes the notion among communities that it is indeed safe to live/build in vulnerable areas, thus attracting people to increased GLOF risks. The Kuruthang area and the Vocational Training Institute Complex in Rangjung were cited as examples of such infrastructure/facilities. It was recommended that the government must lead by example and refrain from taking up these measures. In addition, it was also noted that the government should limit or ban building infrastructure in vulnerable areas to minimize the loss of lives and damage to property.

It was also noted that flash floods and landslides occur annually throughout the country and that the risks posed by these events are far more significant. These small scale disasters damage properties that have long-term impacts on livelihoods of rural communities and local environment. Currently the required level of attention is not accorded to these floods and landslides and their impacts. The need to establish a database on these natural disasters was also discussed to aid in future planning and management of disasters. The idea of developing an inventory on flash floods and landslides featured during the discussion as one possible intervention. The participants also pointed out that the Disaster Management Department should institutionalize an assessment and monitoring system on disasters for effective planning, implementation and decision-making in the future.

The participants felt that currently the roles and responsibilities of disaster management are not very clear and therefore proposed that the Disaster Management Department of the Ministry of Home and Cultural Affairs should take the lead role on disaster management. The Disaster Management Department should, while discharging this mandate, draw upon the expertise, advice and information from different technical departments in planning and implementing programmes geared towards disaster management, including GLOF related programmes in the field. The current lack of coordination among different agencies and therefore the need for better coordination among them was seen as an area of priority for future interventions.

Experiences from other mountain countries across the region were shared and the following were pointed out as successful interventions to date:

- Inventory of traditional practices available with the affected communities;
- Mitigation measures based on local knowledge and practices;
- Incorporating and building on the role of public, financial, industrial and private sectors;
- System of assessment of risk situations with effective monitoring component; and
- Establishment of an effective communication system with a focus at local level.

Recognizing the fact that the limited land resources on which to establish development infrastructure and facilities belong to local people, the following strategies for public awareness on GLOFs were suggested:

- People should be made aware of the risks of GLOFs and that they are the most vulnerable to the consequences of GLOF events;
- Insurance companies should incorporate policy instruments that discourage investment and financing in vulnerable areas;
- Planners and decision-makers should be made aware of the consequences of infrastructure development in vulnerable areas and lead by example;
- The need to educate school children on GLOF mitigation and preparedness through incorporation of GLOF and other disaster risks in school curricula; and
- Promotion and enhancement of audio-visual awareness programmes since these have proven to be the most effective means of communication.

The participants also felt that in order to protect people from the risks posed by GLOFs, an effective early warning system is a necessity. In addition to saving lives, an effective early warning system will minimize damage to property and agricultural land, which constitutes the very basis for rural livelihoods.

There was also unanimous agreement that GLOF mitigation and preparedness should be mainstreamed into government plans, policies and programmes. A government policy decision to this effect is immediately required.

It was also pointed out that programmes on GLOFs should consider the linkages of GLOFs with earthquakes. Since Bhutan lies in an active seismic zone, the possibility of earthquakes triggering GLOFs cannot be ruled out.

The participants also pointed out that, so far most disaster management programmes, including GLOF risk mitigation, have been implemented through donor-funded projects. The participants questioned the sustainability of such projects and recommended that these programmes be mainstreamed into regular government programmes for long-term sustainability.

Ejaz Karim, Earthquake Reconstruction and Rehabilitation Authority (ERRA), Islamabad, Pakistan *(response 2)*

Thank you all for your valuable inputs into the GLOF e-discussion. This is also a growing issue in northern mountains valleys of Pakistan, especially in the Karakuram, Himalayas and the Hindukush ranges.

I have been involved in assessments and inventories of Glacial lakes in localized districts of the Northern areas, notably in Ghizer District situated among the Karakuram and Hindukush mountain ranges. Around 155 lakes were identified through remote assessment and of these 15 were prioritized for physical ground assessment.

I would like to bullet some key activities which can be undertaken for GLOF risk reduction:

- Definition of this specific hazard, its dynamics/ causes should be clearly disseminated to communities in an understandable manner

GLOF is not a generic phenomenon which could be assessed without basic scientific knowledge, although local knowledge is a key factor when highlighting the real situation on the ground. However, the causes of a GLOF may be different, either due to glacial melting depositing sedimentary load at terminus (moraine dams) or the formation of supra glacial lakes due to incision and/or the advancement of a glacier blocking water courses and forming water reservoirs.

- Hazard Mapping

It is very important to assess and map the hazard situation by studying its multiple aspects such as the rate of movement, locations of supra glacial lakes, moraine lakes, water volume, discharges in case of barrier breach, high water current attenuation, sediment load, texture, seepage zones, barrier composition, strength, elevation differences and the gradient of glacier body, zonnation on the basis of movement rate and the estimation of carrying capacity of run-out zone etc.

- Exposure Mapping

All exposures (elements at risk) in the vicinity should be mapped and analyzed subject to hazard magnitude /intensity.

- Risk Mapping

Risk classification can be done by superimposing the multiple layers (demographic, hazard and exposures) and produce risk communication tools for multiple purposes like:

- Awareness raising
- Mitigation (structural & non- structural)
- Capacity building
- Strengthening existing coping mechanism
- Evacuation
- And other crisis management activities

Early warning System (EWS)

- In order to establish an early warning system it is very important to evaluate the indigenous hidden EWS and their coping mechanisms. How the local communities have developed and how it was working in previous catastrophes? What were the gaps? What were the strengths? How it can be strengthened now?

- Highly sophisticated technical system may not be able to work among the community, therefore the local systems should be strengthened by adding easily operatable tools like wireless, FM radio stations etc.

- But the more important thing is to enhance the skills of local volunteers in assessment and monitoring of the reservoirs. Technical assessment levels should be defined and insert gauges

could then be used to develop local skills in regular monitoring and reading of the gauges. Close coordination with government administration should be developed for proper, in-time responses.

Capacity Building

Capacities of the local communities can be enhanced in multiple aspects through the following key interventions:

Institutionalization of the communities

Local organizations can be developed with community volunteers in the form of emergency response teams and trained in specific themes of crisis response and management.

Specialized training in the following themes are crucial for effective risk management:

- Search and rescue (water search & rescue, rope work & management)
- First Aid (causality handling, triage, first aid subject to injuries etc)
- Information and communication (Base line information gathering, EWS and monitoring, damage and need assessments)
- Administration and logistics (evacuation, camp management, relief etc.)

Mitigation

Some structural mitigation options can be implemented for reducing impending risk

- Create a spill way**:** In case of moraine dam (if water volume is limited) prior to the melting season a spill way can be dug out and the floor should be pitched with boulders to avoid down cutting. When the melting season starts water will not accumulate and maintain its least level. In case of full water in the reservoir, it can be drained out by pumping during the freezing season and then a spill way can be designed.
- Along the run-out zone the bottlenecks should be clear to avoid the bed clogging while at some susceptible spots side embankments can be strengthen with thick gabion walls.
- Low lying bridges or obstacles should be removed or elevated to avoid retention of the material.
- Huge trees or trunks should be removed from the surrounding cross-sections.
- Telephone and power lines should not be erected around the run-out area.
- Vulnerable houses, commercial areas, critical facilities should be avoided from the risk locations as identified in the mapping.
- Land use planning rules should be enforced.

Challenges

- Detailed hazard mapping requires huge investments and sophisticated equipment and data
- Trained professionals in specific fields are not available
- Big gap between communities, researchers and policy makers
- Attitude of government officials
- Volunteer spirit among communities
- Weather and accessibility
- Lack of institutions, data, capacity and access to data

Pelzang Wangchuk, Consultant, Thimphu, Bhutan

Among others, firstly the studies by ICIMOD, Bhutan Department of Geology and Mines, and few other organizations, and secondly the repeated occurrences in the past are two primary reasons to believe and prepare for GLOFs in Bhutan. Given this conditional probability, monitoring of water level in the lakes identified as posing outburst, siphoning out water from these lakes, conducting awareness campaign, and establishment of early warning system are few activities that have been started. The Government has also established the Department of Disaster Management which is indicative of the fact that GLOF issue cannot be left under a single sector.

My association on disaster management, particularly GLOFs, is recent. I may also mention here that this association is limited to one case study in Samdingkha in Punakha Dzongkhag. While there may be other issues still to be discovered, I would like to share some of the issues that I have learnt so far through this case study. I hope these issues and challenges will attract the attention of different stakeholders involved in designing and implementing field activities to avoid disaster at the time of GLOF.

Spoon-feeding complex

Be it in a community meeting or in an informal chat, a general view of the people on dealing with GLOF, or in that matter with regard to any disaster, is that the Government will do everything for them. No one asks "What can I or we do?" On the other hand, the people know that their own properties and lives are at risk. Such dependency on the Government has an adverse implication on the role played by communities in implementing and sustaining community-based mitigation measures.

Low community bond

Another weakness is a very low level of spirit among the people in Samdingkha to help one another. One reason for this social weakness is the development itself. Modern communication facilities are available. Second reason is that the people are from different settlements. Thirdly, GLOF is not an annual feature and people do not know exactly when it will happen. The Gup sadly said, "The people of Samdingkha have no community bond on which to capitalize planning and implementation of GLOF reduction and preparedness activities".

Unpopular infrastructure development

There are public infrastructure and facilities developed on the areas that are identified as red zones. For examples, the feeder road connecting Kuruthang with Samdingkha is aligned along the bank of Pho Chhu. Kuruthang itself is classified under red zone but it is being developed into a booming social and economic centre. These examples of development of public infrastructure and facilities are cited by people when reminding them of potential risk of developing personal or community assets in their private land falling under red zones. If Government can develop Kuruthang, we can develop Samdingkha as our rural town, the people of Samdingkha say.

GLOF is making of God

The people of Samdingkha have vast knowledge about GLOF, including some of the lakes. However, they believe that God is watching them and is designing whatever is happening. Consequently, local religious leaders, occasions, and objects contain an element of protection from evils, including GLOF. These people will remain religious-minded for years to come. Therefore, due recognition and appropriate role to the local religious leaders, occasions and objects in designing a GLOF programme is critical.

Decision-making v/s attendance in meetings

A high rate of attendance in a community meeting is often equated with the willingness of the people to participate in GLOF. My personal observation is that only one or two, if at all, contribute to information sharing and decision making. It is still a Bhutanese way of life to attend meetings when convened by their Gup. Also, let us not forget that GLOF is not an annual feature to keep people on their alert. The point here is what strategies can be employed to garner active participation from the communities for whom GLOF risk reduction measures are meant for. Another related issue is the need to focus on the vulnerable communities and not those who are involved because they are from the same Gewogs. Targeting the actual vulnerable communities will be more effective both in term of management and use of scarce resource.

Planning and meeting fatigue

Different stakeholders have been in touch with the people telling them about the possibility of GLOF, the need for early warning systems, lack of capacity at the community level, the need to institutionalize GLOF into broader development programmes, and the like. While it is necessary to keep in touch with the

people, taking too long a time to deliver what has been discussed ushers a planning and meeting fatigue in the people. Also repeated visits can be misinterpreted by the people as if a flood is already occurring. Remembering numerous visits in recent past by outsiders in connection with GLOF, a lady attending a GLOF meeting held in Samdingkha asked, "Is the flood coming?" It is time to act in the fields without waiting for GLOF to occur.

Local institutions not fully involved

Gewog administration and Throm (town) Committee of Samdingkha are aware of the GLOF activities in their area. These are local institutions that can make things happen and are willing to contribute to GLOF activities. More importantly, these are people's institutions and they function under the direction of these institutions. Currently, these institutions do not know their role and also have no capacity with regard to GLOF responsibility. Within the disaster management framework which extends to Gewog level, it is time to take on board these institutions by providing them with necessary capacity development and functions.

These issues are detailed out in the case study report that will be published soon. The underlying fact is we need to act on these issues immediately. We cannot afford to wait any longer since we are dealing with Nature.

Arshad Ashraf, **National Agricultural Research Centre, Islamabad, Pakistan**

It is a good effort to provide a platform for exchanging information about GLOF hazards and share valuable experiences with other stakeholders. I want to discuss some pre-GLOF, in-GLOF and post-GLOF challenges faced by local communities and management in the northern areas of Pakistan.

Recently, the impacts of climate change have been observed in the shape of extreme flood events in a series from 2004 to 2008 in the Indus plain, western Balochistan and now in the Northern areas especially in Hunza River basin - one of the glaciated valleys of the Karakoram region of Pakistan. The prediction of sudden flood or GLOF hazards remains a challenge for Northern communities. GLOF hazards triggered by earthquakes i.e. in Hindu-kush and lower Himalayas are mostly difficult to predict like the earthquake itself. In future hazard assessment of such GLOFs, micro-seismic zonation can help in developing GLOF hazard zones.

In Karakoram region particularly the glaciated valleys of Gilgit, Hunza, Shigar etc. where earthquake effects are not high up, the development of englacial ponds/lakes in valley glaciers pose a great challenge. Careful monitoring and investigations based on remote sensing and ground surveys (geological and geophysical) of such lakes/ponds would be required for anticipating sudden GLOF hazards in the future. In the less extensive glaciated parts of southern Karakoram range, the lakes mostly end-moraine dammed and valley types pose a risk of GLOFs downstream for which regular aerial monitoring is required. The major challenge lies in effective investigation of climate change in this Himalayan region which is playing an influential role in all these situations.

There are challenges in properly responding to GLOF and flash flood hazards as most of the local communities lack any preparedness mechanism and setup for risk reduction and hazard mitigation. In remote areas like upper Hindukush, Karakoram and Himalayas, where communities are generally poor, they pool their resources to cope up with such hazard situations on a self help basis. Outside help is often not available due to meagre communications and accessibility.

In post-GLOF situations , the communities - especially women, children and elderly - face problems of physical and mental unrest due to dislocation and loss of livelihood. The proper rehabilitation and restoration of their livelihood remains a challenge for local government and management.

Many thanks to all who contributed to this discussion

If you have further information to share on this topic, please send it to Solution Exchange for the Disaster Management Community in India at se-drm@solutionexchange-un.net.in and/or Solution Exchange Bhutan at se-bhutan@solutionexchange-un.net.bt with the subject heading "Re: [se-drm] Discussion: GLOF Risk Mitigation - Key Issues, Challenges and Approaches. Additional Reply."

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