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Early Warning System for Disaster Risk Management

Knowledge brief On training and capacity building needs

Focus on GLOF risks related to South Lhonak Lake and Shako Chho, Sikkim

March, 2023

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We hope that our sincere efforts in bringing forth this document will be useful for training and capacity building for GLOF management in the State.

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Disaster Risk Management Planning and Implementation Support in the Indian Himalayan Region

Contents

1. Introduction

Over the last decades, serious threats related to Glacial Lake Outburst Floods (GLOFs) have emerged around the world. Glacial lakes have caused some of the world's most devastating floods, for example in the Andes, Alps and Himalayas, where thousands of life losses and serious damages have been reported (Huggel et al., 2020). The State of Sikkim is no exception and both South Lhonak lake and Shakho Chho, in the northern part of the State, pose a serious threat of GLOF hazard in the downstream region (NDMA, 2020b; Tripathi et al., 2022). Realizing the hazardous potential of GLOF, it is essential to devise proper risk reduction strategies for the downstream communities (Sharma et al., 2018; Samui and Sethi, 2022; Hazra and Krishna, 2022). Early Warning Systems (EWS) are risk reduction measures, that use integrated communication systems to help communities prepare for and respond to hazardous events. A successful EWS saves lives and jobs, land and infrastructures and supports long-term sustainability (UNISDR, 2012). However, there is no GLOF EWS in the State of Sikkim. Further, there is little awareness about GLOFs, especially among vulnerable social groups (e.g., migrants; Samui and Sethi, 2022). Therefore, there is an urgent need for setting up a GLOF Early Warning System along with awareness, training and capacity building activities spanning across different administrative levels, from national to local.

Under the auspicious of the Swiss Agency for Development and Cooperation's (SDCs) Global Programme Climate Change and Environment (GPCCE), India is supporting the operationalization of climate change adaptation actions in the mountain states of Himachal Pradesh, Uttarakhand and Sikkim through the phase two of the "Strengthening Climate change Adaptation in Himalayas" (SCA-Himalayas) project that was launched in 2020. The project aims to contribute to the evidence needed to support policy and strategies to strengthen climate resilience of mountain communities. It envisions transformation of existing capacities in water resource management and DRM in mountain ecosystems to design actionable, scalable and replicable strategic interventions to enhance resilience of the local communities. The direct beneficiaries of the project will be the officials and institutions at the sub-national and national level. The project will also inform officials/institutions at the regional level and will lead relevant discussions/processes at global level, while the indirect beneficiaries will be the communities who depend on/are affected by climate sensitive sectors. The project involves the implementation of approaches for Disaster Risk Management (DRM) that have not been tested in India yet. More precisely, it will support the development of early warning and response systems.

In the State of Sikkim, so far the efforts undertaken in a previous phase of the project ("Strengthening State Strategies for Climate Actions - 3SCA" from 2016 to 2019) were focused on reducing the lake water level by syphoning and widening of the outlet of the South Lhonak lake, located in the upper valley ahead of Northern Sikkim. The current phase of the project will focus on designing and supporting the development of an integrated early warning and response system for GLOF at the South Lhonak lake and the Shakho Chho, which will be the first of its kind in the country. The implementation of the EWS is expected to benefit a population of 70,000 people that reside along the banks of Teesta River that could get affected from the lake outburst flood.

In that respect, one of the activities of this project is to conduct an in-depth assessment of Early Warning System (EWS) training and capacity building needs. The analysis addresses topics relevant for the EWS design, implementation, and effectiveness, including e.g., allocation of institutional responsibility before and during a warning, use/interpretation of data and scientific advice for decision making, connection between official warning messages and resident's responses, engagement of the media, false-positive and negative alarms. The assessment will thus focus not only on technical but also institutional, social and economic capacities and regulatory aspects relevant for the EWS implementation and long-term maintenance.

In this knowledge brief, capacities necessary for GLOF risk management are explored with a focus on designing and implementing a EWS and on achieving a level of preparedness by each person or organization receiving a warning, which allows them to take actions to save their lives or reduce potential impacts. Knowledge, preparedness, technical, response and communication, legal, institutional and economic capacities have been analysed.

2. Background

The State of Sikkim is situated in the Himalayan region (northern part of India) and borders the Tibet Autonomous Region of China in the north and northeast, Bhutan in the east, Nepal in the west, and West Bengal in the south (Fig. 1). It covers an area of 7,096 km^2 and is divided into 6 districts, i.e.: Gangtok, Pakyong, Gyalshing, Soreng, Mangan and Namchi.

Sikkim is a small and mountainous state in the Indian Himalayas, therefore characterized by extreme topography and altitude. Its elevation varies from about 300 m asl in the south to 8,586 m asl (Mount Kangchenjunga - third highest mountain in the world), leading to an Himalayan type of climate described by low temperatures, high rainfall on windward slopes, comparatively dry on the leeward side and heavy precipitations in the form of snow at the mountain tops. In that respect, Sikkim shelters numerous glacial lakes in high altitude glacierized terrains including one of the largest and the fastest-growing South Lhonak lake (Sattar et al., 2021; Fig. 1). These lakes are expanding due to accelerated glacial retreat and melting resulting from climate change impacts (Kumar and Prabhu, 2016), leading

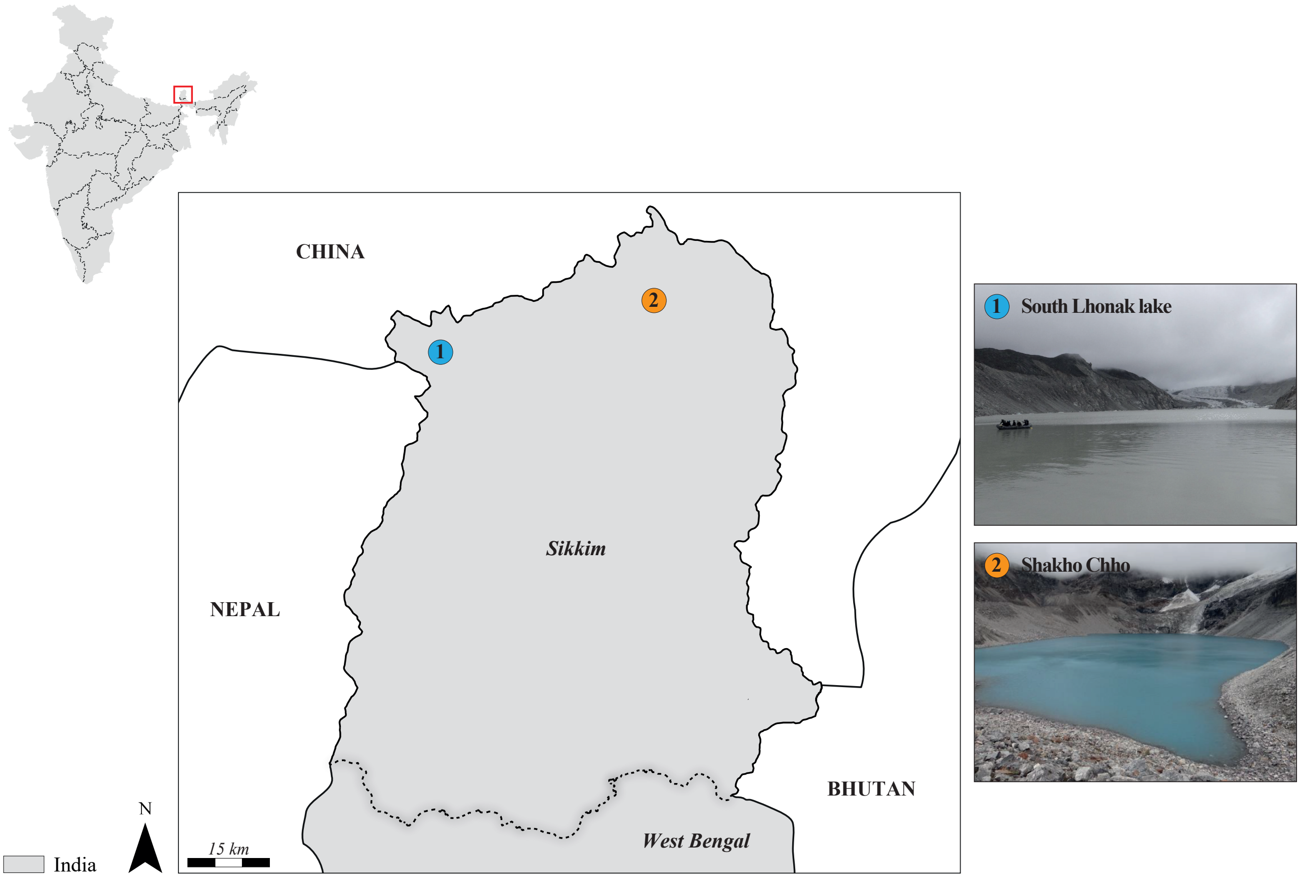

Figure 1: Sikkim State, own elaboration (©Pictures: DST Sikkim)

to a potential increase of related hazards such as Glacial Lake Outburst Floods (GLOFs). Similarly, Sikkim's rural population is slowly increasing (around 75% of the total population of the State lives in the villages of rural areas; Census of India, 2011), some of them being highly exposed to GLOF hazards (NDMA, 2020b). Even higher exposure may also be expected in the future due to further rural expansion, industrialization, agriculture and tourist developments. As a consequence, the risk of glacial lake outburst floods is rapidly increasing in the State of Sikkim.

3. GLOF hazard in Sikkim

Work to date in Sikkim conducted under the project Disaster Risk Management Planning and Implementation Support in the Indian Himalayan Region, has focused on a first-order, desk-based analyses of GLOF risk for the entire state, followed by detailed GLOF modelling for identified critical lakes of South Lhonak lake and Shakho Chho (Sattar et al., 2022). The approach being followed in Sikkim aligns closely to National Guidelines established for the assessment and management of GLOFs (NDMA, 2020a). Several key conclusions thus far are summarised below, with implications for GLOF disaster risk management planning in Sikkim.

- Sikkim is a clear hotspot of GLOF risk, with potential impact on communities, roads, agricultural land, and hydropower infrastructure (Fig. 2)
- Ten high priority lakes have been identified in Sikkim, based on multiple lines of independent evidence coming from different studies and investigations combined with the latest assessment. This includes South Lhonak lake and Shakho Chho, justifying the selection of these lakes for piloting an early warning system
- In the case of South Lhonak lake, the GLOF threat will increase over the next decades, as the lake can continue to grow, increasing the volume of any potential outburst event, but also increasing the susceptibility of the lake to large impacts of rock or ice coming from the mountain headwalls
- Arrival time of a large-magnitude GLOF from Shakho Chho to the first downstream community (Thangu village) is only approx. 7 min, and reaches Chungthang hydropower reservoir within 1 hour (longer warning times possible depending on the modelled scenario)
- Due to its location next to the river and short warning time, Thangu is a very critical high-risk situation, and would be heavily affected, even under a moderate GLOF scenario. Options for evacuation routes and safe zones are very limited
- A large magnitude avalanche-triggered outburst from South Lhonak lake would have an arrival time of around 3 hours in Chungthang. The resulting peak discharge of up to 2000 m3 s-1 is considered extremely unlikely to lead to catastrophic failure of the hydropower dam at Chungthang
- Downstream from Chungthang, the GLOF would rapidly reduce in magnitude, and while some bridges could be damaged, there is low risk to settlements or other hydropower reservoirs

These key conclusions have formed the basis of discussion with local stakeholders, and underpin the design of Early Warning Systems that will reduce the risk of GLOFs in Sikkim.

4. Disaster risk management for South Lhonak lake and Shakho Chho, Sikkim

In the State of Sikkim, as elsewhere in the Himalaya, mass movements of ice and/or rock are considered to be the potential triggering factors of GLOF events. In addition, an increase in water level and lake size due to accelerated glacial retreat and melting resulting from climate change impacts also results in increased hazards from GLOFs (Worni et al., 2013; Allen et al., 2016; NDMA, 2020b; Fig. 3).

GLOF risk to the population is high in the State of Sikkim and such events also represent a major threat for agriculture and hydropower facilities. Unfortunately, there is no GLOF EWS presently in the State. Yet, in order to reduce the risk relating to GLOFs, high density polyethylene (HDPE) pipes

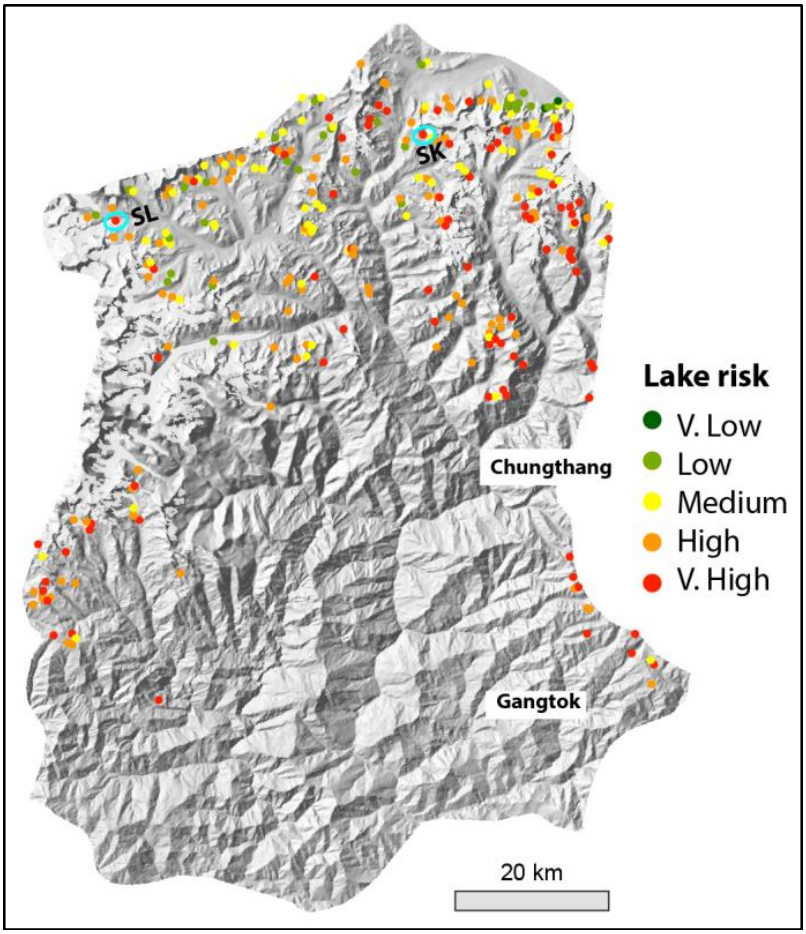

Figure 2: Results of the GLOF risk assessment to settlements across Sikkim. South Lhonak lake (SL) and Shakho Chho (SK) are indicated (©Simon Allen).

have been installed in, e.g., South Lhonak lake (Fig. 4). In greater details, a total of 140 pipes were used for the siphoning of lake and for therefore lowering the level of water in the lake. However, this technical risk mitigation measure is not entirely sustainable in the long term. Thus, to guarantee higher safety standards, there is a need for EWS.

The State of Sikkim authorities already developed a Disaster Management Plan, that includes four volumes and has been updated in September, 2015. The involvement of the local community is part of the current DRM framework and an Incident Response System is part of the DRM protocol. At present, Sikkim State Disaster Management Authority (SDMA) and District Disaster Management Authorities (DDMA) are organising awareness campaigns through the capacity building fund from the State Disaster Response Fund (SDRF). Apart from this, the National Disaster Management Authority (NDMA) is also providing assistance to the State through the Aapda Mitra scheme for training volunteers in flood preparedness. In Sikkim, under this scheme, SDMA is conducting disaster management training of volunteers across the State. At the time of this writing (August 2022), more than 300 village volunteers have been trained under this scheme.

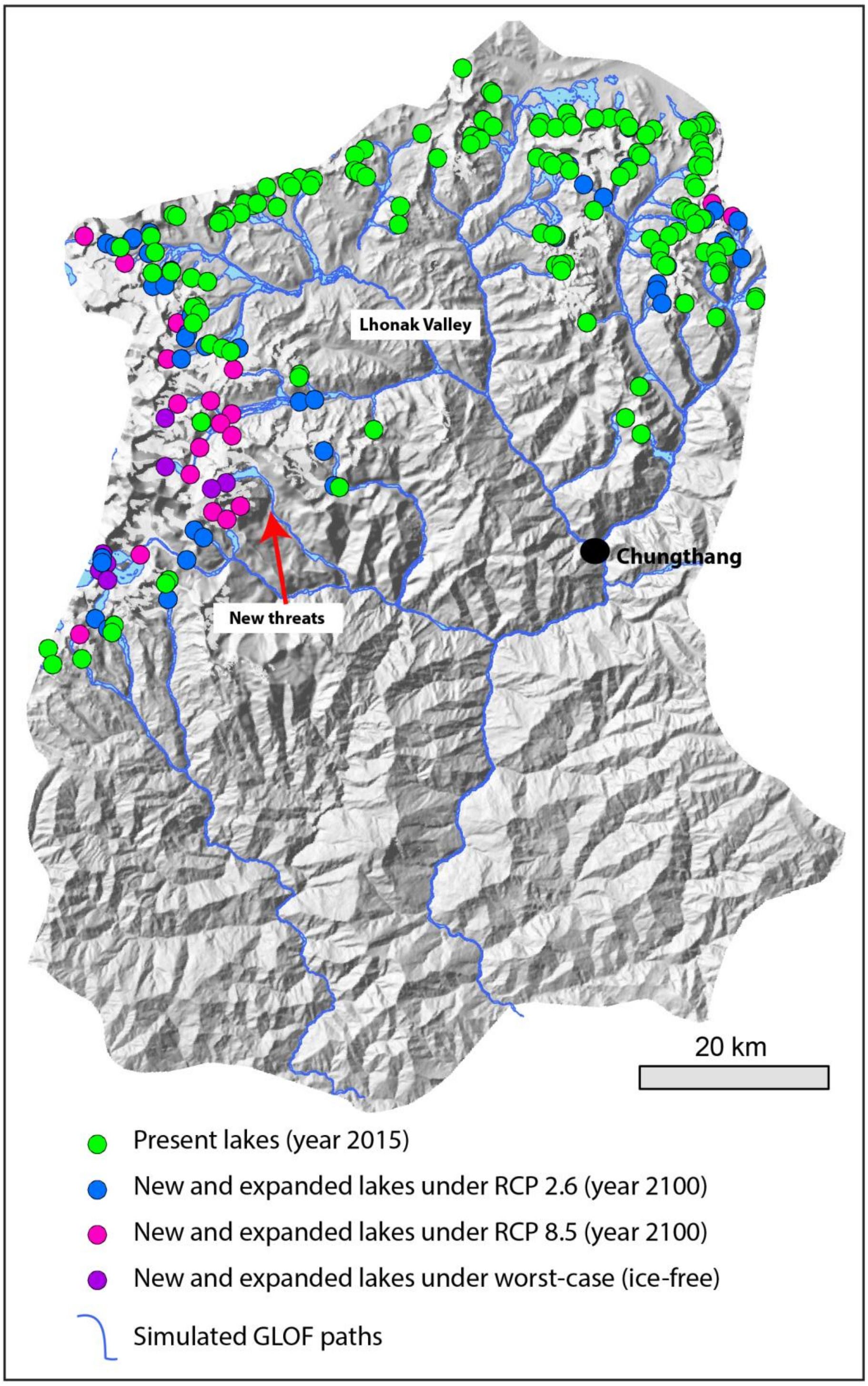

Figure 3: Projected future glacial lake development across Sikkim, until the year 2100 under RCPs 8.5 and 2.6, and considering a worst-case ice-free scenario (©Simon Allen).

5. Conceptual framework and methodology

Over the past few decades, guidelines and recommendations for EWS design increasingly encouraged the transition from top-down, command and control style of management to "people centered" approaches (Basher, 2006; UNISDR, 2012; WMO, 2013; Scolobig et al., 2015; Preuner et al., 2017), empowering

Figure 4: Siphoning of South Lhonak lake, Sikkim (Sharma et al., 2022)

"individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner to reduce the possibility of personal injury and illness, loss of life and damage to property, assets and environment" (WMO, 2018: 3). Some key characteristics of people-centred warning systems include a stronger focus on capacity building, stakeholder engagement and responsibility sharing, enhanced communication supported by technological innovations, and inter-agency collaboration. This results -among others- in a much stronger focus and shifting of resources to the local level, including training, warning awareness and communication activities. Communication and response capability is also one of the 4 key components of EWS, including (UNISDR, 2012; WMO, 2018): (*i*) Risk knowledge (e.g. Are the hazards and vulnerabilities well known? What are the trends of those factors? Are risk maps and data widely available? Do the risk maps consider future scenarios?); (*ii*) Response Capability (Are response plans up to date and regularly tested? Are local response capacities well developed? Are people prepared and ready to react?); (*iii*) Monitoring and Warning Services (e.g. Are the right parameters being monitored? Is there a sound scientific basis? Can accurate and timely warning/alarming be generated?); (*iv*) Dissemination and Communication (e.g. Do warnings and alarms reach all those at risk? Are the warnings and alarms useful, usable and used? Do warnings trigger protective behaviours?) (Fig. 5).

In parallel to become people-centred, those implementing a warning system must know who their audience is and conduct meaningful engagement to understand existing capacities, tools available, level of knowledge, and information requirements for an optimal response (Zhang et al., 2019). Indeed

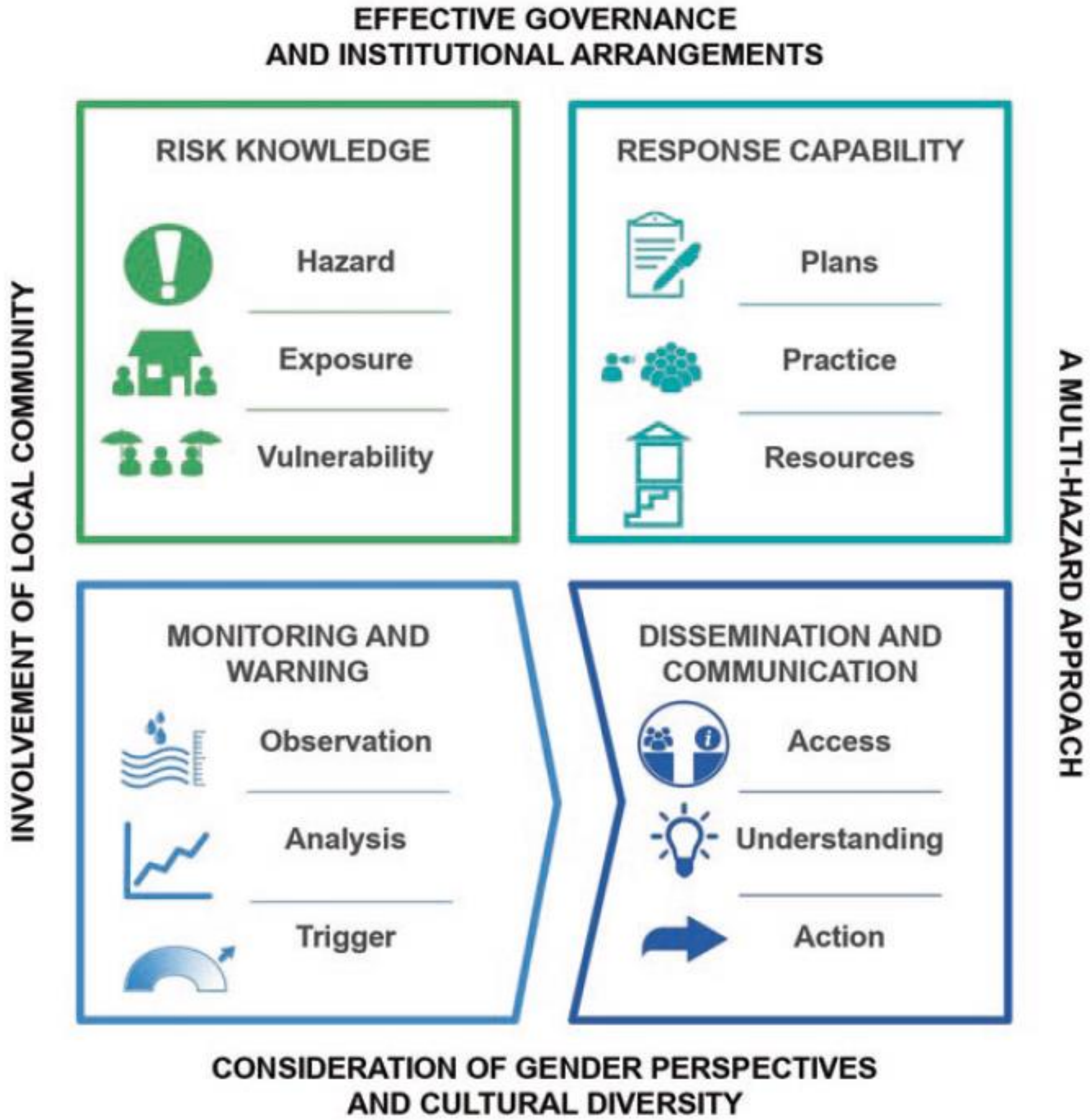

Figure 5: EWS components, based on Golding, 2022

the EWS development is a highly dynamic process, in which success is determined not only by the efficiency of the technologies in place and by the availability of accurate data, but also by the capability of the warner to provide 'fit for purpose' information and by the response and adaptive capacity of the receivers. An effective EWS also critically depends on the creation of good partnerships among those creating, communicating and responding to warnings. Thus, successful EWS operation requires long-term commitment of funding and stakeholder engagement, including local communities, government departments at different levels, private sector, media and regional players.

Research increasingly shows that the social components (e.g., community involvement, communication) and the technical aspects of an EWS are of equal importance. However the social aspects are often overlooked (Golding, 2022) and this can cause serious collateral effects. For example in the development of a GLOF EWS project in the tropical Andes of Peru, local inhabitants first requested to remove the

EWS and afterwards dismantled the EWS station based on the wrong assumption that the rain gauges and antennas were responsible for the lack of rainfall and drought that hit the region (Huggel et al., 2020). In another EWS project in the Austrian Alps, the community has strongly opposed the EWS substantial investment of tax money to cope with a risk affecting 100 out of 15,000 residents (Preuner et al., 2017).

Based on these and similar cases reported in the Himalayas, Andes and Alps of Europe, it is strongly encouraged to give the social sciences a more prominent role in EWS development (Huggel et al., 2020). Beside the identification of potential intra and inter-community conflicts, the analysis of EWS capacities and social components can considerably contribute also to improve warning communication and dissemination. For example warning communication research highlights that factors that influence receiver's behavioural decision making during a warning include not only message characteristics (e.g., content), channel access and preference (e.g., cell phone, TV, radio) and information sources (e.g., message frequency) but also receiver characteristics (e.g., age, physical abilities), environmental and social cues (e.g., receiving information from family/friends), context (e.g., knowledge on escape road). All these factors need to be taken into account when designing and implementing EWS.

Thus, critical questions are: how to develop dynamic EWS? How to classify and analyze warning capacities? How to identify barriers and leverage on enablers to improve existing capacities? These questions together with a review of the literature on EWS development and warning communication set the stage for the in-depth EWS capacity assessment conceptual framework. Tab. 1 provides an overview and definitions of the key capacities enabling successful EWS, namely: (1) knowledge, (2) technical, (3) economic, (4) response/communication, (5) preparedness, and (6) legal/institutional capacities.

Knowledge	Set of early warning system (EWS) related data, information, but also skills, abilities, and qualifications of EWS target group members
Technical	Technical devices installed (e.g., camera, sensors, installations) to guarantee the observation (monitoring) and warning system functioning and effectiveness
Economic	Financing and economic resources provided by multiple public and private organizations to supper warning system installation and maintenance
Preparedness	Knowledge, skills and abilities necessary for people to know how to behave during a warning, and more generally, an event/disaster
Response and Communication	The set of information sources, channels and tools that allow effective spread of warning messages to the local authorities, emergency managers and residents
Legal and Institutional	The legal and institutional frameworks that allow a good functioning of a warning system

Table 1: Capacities considered in the in-depth assessment framework

In order to analyze these capacities, the study design consisted of two phases: a desk study and semi-structured interviews. The desk study included the collection and analysis of relevant documents, such as newspaper articles, laws, technical reports from the local authorities, disaster management plans, research reports, scientific articles, and books. The semi-structured interviews focused on 3 target groups, i.e., local authorities in charge of communicating warnings to the public, emergency managers and public/community leaders.

The interview protocol has been structured around the six types of capacities presented in Tab. 1. It included a total of 60 open ended questions. For example questions related to knowledge capacities included, e.g., "*Do you think that GLOF risk in your area will change in the future, and what would be the main driver of this change?*". Technical capacities have been assessed through several questions addressed to local authorities and emergency managers including, e.g., "*How good is the mobile network coverage (type of signal, provider)?*". Communication capacities have been analyzed with questions such as "*Are warnings generally understood by people and useful for them?*" or "*What type of channels and messages are most effective?*". Legal and institutional capacities include questions as, "*Are there any legal issues related to the EWS development (e.g. insurances or role of the public and private sector)?*". The protocol ended by asking interviewees some reflections about key strengths and weaknesses of the existing system to alert/warn the population. The interview protocol is available in Annex A.

As mentioned above, the methodology included: (*i*) a desk-based review focused on topics relevant for the EWS design, implementation, and effectiveness for South Lhonak lake and Shakho Chho in Sikkim; (*ii*) consultation with 83 stakeholders by means of targeted semi-structured interviews (face-to-face), one workshop and one online meeting (presentation on draft knowledge brief on EWS training and capacity-building needs). The 83 consulted stakeholders included: a) 49 attending the project inception workshop on July 12, 2021 (for the minutes see Annex B); b) 12 attending the online meeting for presentation of draft knowledge brief on September 30, 2022 (for the minutes see Annex C); c) 22 interviewees contacted between March 14, 2022 and March 22, 2022. These stakeholders represented different sectors and administrative levels, as well as non-governmental entities involved in disaster risk management, including, e.g.: the ex-Panchayat President; the Sub Divisional Magistrate; Teesta Urja Limited and a local resident of Chungthang; The Nagar Panchayat of Singtam; The Nagar Panchayat and the Sub Divisional Magistrate of Rangpo; The District Magistrate and the Deputy Director Disaster Management of Mangan; The National Hydroelectric Power Corporation and the Teesta V Power Station (NHPC) of Balutar (see Annex D for a list of the stakeholders involved).

In the following sections, we provide an overview of the key findings concerning the EWS capacities and needs assessment in the South Lhonak lake and Shakho Chho, Sikkim. We report on the stakeholder's expected challenges in the design, implementation, operation and circumstances around the setting up of an EWS for GLOFs. Text in italics corresponds to interview excerpts.

6. Findings

The State of Sikkim is highly vulnerable to GLOF and both South Lhonak lake and Shakho Chho, in northern part of the State, represent a serious threat (Fig. 1; NDMA, 2020b). Given the location within the seismically active and topographically steep Himalaya range (NDMA, 2020b), mass movements of ice and/or rock are assumed to be the main triggering factors of GLOFs, endangering numerous areas in Mangan (North Sikkim; Fig. 1) including far downstream. In greater details, prone areas include, e.g., Muguthang, Thangu, Lachen, Chungthang, Dikchu, Adarshgoan, Singtam and Rangpo. Additional specific sites, such as army settlements (e.g., ammunition depot towards Lachen), food processing companies in Mining city, or the Chungthang dam are highly exposed. Assessment undertaken under the current project confirms that South Lhonak lake and Shakho Chho pose a high or very high risk to all sectors (NDMA, 2020b). Shakho Chho generally has a high risk rating, owing to the closer proximity of the lake to villages, roads, and hydropower plant (Nitesh R, 2013). In contrast, the uppermost 40 km of a potential GLOF path from South Lhonak lake passes through uninhabited high alpine and forested land.

Interviewees maintain that the risk resulting from GLOFs will become even higher in the next decades in Sikkim. This is confirmed by recent studies, showing, for example, that the volume of South Lhonak lake will increase by up to 75% relative to today, as the terminus of the glacier retreats up to 1.2 km from its current position. The main driver of this future change is unquestioningly global warming. Yet, future risk is not only related to climate changes, but also to population migration, hydropower expansion, and further tourist development (unregulated tourist inflow) both resulting in even higher exposure of the population and properties. Similarly, the polyethylene pipes installed in South Lhonak lake are choked due to falling boulders so that their effectiveness and impact on GLOF risk are significantly reduced if not regularly maintained.

More broadly, the vast majority of the population has basic knowledge of river flooding in case of monsoon and cloud burst, but sufficient knowledge of GLOF phenomena and potential consequences is seriously lacking. As a consequence GLOF evacuation plans are nonexistent and communities are not well prepared to face such events. Another critical aspect is related to seasonal migrants, or workers of private companies, that are not quite familiar with the place and thus do not know where to evacuate (safe places) in case of an event.

Furthermore, numerous critical infrastructures (e.g., Wai-Wai factory, next to Teesta river in Mining) or human settlements are located along river banks, but the latter ones do not have any safety walls or embankments for protection. Indeed, army settlements near the river have been already washed away during previous flood events. Similarly, constructions have been built (difficult for authorities to constrain constructions on hazard zones), and roads/footpaths are narrowed, limiting access to potential safe zones. Areas are also crowded and roads have heavy traffic both resulting in serious difficulties to escape in case of an emergency situation.

As mentioned above, there are no EWS to minimize GLOF risk in Sikkim (limited/nonexistent funding for warning systems and its maintenance is a key issue, see also Section 7.5). Yet, in practice, mock drills are conducted by the disaster management authorities for fires, earthquakes, and when water level rises due to monsoon. Similarly, Standard Operating Procedure (SOP) is available with specific reference to dams. For example, in Teesta Urja, awareness has been generated amongst the employees, both at the dam site and power house site. As per the SOP for Early Warning, the response is dependent on the level of threat. There is a Command Control Room crewed 24 hours throughout the year, and in monsoon season, a Quick Action Team is responsible for information dissemination and action (people and equipment's to be saved, how to save themselves and as well as communicate downstream). Teesta Urja also uses sirens to inform people of water discharge/or when releasing water. The latter are automatically sounded through GSM mobile. If sirens are not sounded, a message is received wherein the guards placed at respective places manually sound the sirens. In that respect, people are quite familiar with alerts, and separate sirens/alarms could therefore be adapted to GLOF events.

Furthermore, mostly local inhabitants are connected and actively interacting via digital tools (e.g., WhatsApp). For example, Teesta Urja Limited company relays hourly information on how much water is released by dams. Mobile communication could therefore be promoted to, for example, complete information on GLOF (e.g., mobile application with resource map, evacuation route, alarm system, contact points, real time river water level, emergency contacts, government branded property for instruments and equipment etc.). Yet, the communication network needs to be tested/strengthened as it already failed in the past (e.g., mobile communication was down in 3-4 hours due to an earthquake event in 2011). Interviewees also maintain that it is essential to ensure that the most vulnerable and marginalized social groups are included in the warning communication and dissemination plan.

Finally, local communities are poorly involved in the design and implementation of warning systems and too few initiatives (e.g., participatory processes to co-design EWS) to increase community preparedness and GLOF/EWS knowledge have been conducted. Consequently, opposition, vandalism or robbery may appear for multiple reasons, e.g., negative perceptions of warning systems (e.g., false rumors in the past leading to theft in private property), opposition to EWS installation because of the excessive costs of the equipment's (e.g., as opposed to public money investments in other services addressing community basic needs). In that respect, the community needs to be involved in the EWS co-design, maintenance of devices and informed about the importance of the equipment being installed including the benefits of the measurements and EWS. At the technological level the equipment being installed should discourage robbery (e.g., webcams, supervision system, fencing, installation near army camps, etc.). These characteristics may be included in the design of the equipment in order to make it difficult to remove the parts of interest. Also, another design element could be to install the equipment in locations which are difficult to access, although this could then reduce the ability for regular and safe maintenance of the system.

7. Addressing local needs to improve EWS capacities

7.1 Knowledge capacities

7.1.1 Risk awareness and stakeholder's perspectives about GLOF hazard

Interviewees maintain that one main weakness results from the low level of awareness and understanding of GLOF events at the local level. Indeed, "*since there has been no GLOF awareness program in the past, communities do not have sufficient GLOF knowledge*" (int. 3 community leader). On the one side a vast majority of interviewees agrees that GLOF risk awareness is low, on the other side they are also hardly aware of any risk perception survey conducted in the area that could provide evidence about resident's attitudes, behaviours and opinions concerning GLOF. A recent social vulnerability field survey (Samui and Sethi, 2022) shows that migrated households have more vulnerability and adaptive capacity than permanent households. It also reveals lack of participation in the SSDMA and LR&DM awareness programs by the migrated population compared to the permanent residents. This is simply an example that shows how risk is known and perceived in different ways by different stakeholders. It is thus a challenge but also a necessity to first understand and then take into account different perceptions for the EWS acceptance and long term success of risk reduction measures.

There is also shared agreement that an accurate communication of the key GLOFs elements is crucial to make people aware of the level of risk and how it might increase in the future, including in zones that may currently face no risk. To improve awareness, local disaster risk managers and raising awareness groups are considered effective options. On the contrary, the majority of interviewees believes that citizen science initiatives (e.g., to collect data that can be used for monitoring purposes) will not be successful primarily because of limited interest/participation.

7.1.2 Communication about the EWS (implementation/functionality)

According to the interviews results, a weakness results from the absence of communication regarding the importance and the reasons why an EWS is essential to guarantee adequate safety standards. Indeed, local inhabitants are poorly involved in the implementation process of warning systems and too few initiatives to increase EWS knowledge have been conducted. Consequently, chances are very high that the new equipment may be stolen or destroyed. This underlines the fundamental importance of engaging with the residents as close as possible, and as early as possible, in order to let them understand that EWS in the first place are for their benefit.

7.2 Preparedness capacities

At present, SDMA and DDMAs are organising extensive awareness campaigns through a SDRF supported capacity building fund. Apart from this fund, NDMA is also providing assistance to the State through the Aapda Mitra scheme for training volunteers in flood preparedness. In Sikkim, under this scheme, SDMA is conducting awareness raising and training on disaster management to volunteers across the State. To date more than 300 village volunteers have been trained under this scheme. GLOF EWS training modules (e.g., on hazards and vulnerability, warning signals, communication, evacuation maps/route/process and response) need to be developed and disseminated to the trained volunteers through SDMA and DDMA. In addition, training of officials from State Departments (SDMA, DDMA, Power Department, Roads and Bridges, Mines and Geology, Water Resource Department and others), Central Organisations (CWC, GSI), Paramilitary forces (Army, ITBP, BRO) and Hydro power corporations (Teesta Urja Ltd, NHPC) need to be undertaken to raise awareness about existing GLOF vulnerability.

7.2.1 Emergency and warning protocols for stakeholders

The ability of people at risk to appropriately respond to the levels of warnings and alarms issued is one of the critical elements of an EWS. Yet, the majority of consulted stakeholders mentioned that communities/residents are not quite prepared for GLOF events. The residents often ignore the procedure to follow in case of an event ("*do's and don'ts, what to do and when?*"; int. 1 community leader) and "*have no idea where to go*" (int. 1 community leader). Information on (*i*) how to proceed (i.e., emergency plan) and (*ii*) evacuation routes/places "*are to be clearly disseminated to the public*" (int. 7 emergency managers/local authority). Such information is even more important to be disseminated because "*most of the migrant workers, workers of private companies, etc. are not quite familiar about* *the place and not aware and prepared for GLOF like event*" (int. 3 community leader). Interviewees also mention that community leaders - as opposed to e.g., emergency managers - are often not even aware of the existence of the District Disaster Management Plan. In conclusion, emergency and warning protocols represent essential elements of an EWS and need to be provided. These protocols should document and define GLOF warning procedures, by differentiating a number of warning levels and associated actions as well as the responsible authorities.

7.2.2 Evacuation plan

There is a critical need to develop GLOF emergency procedures and evacuation plans in Sikkim. Indeed, interviewees maintain that "*evacuation plans need to be designed*" (int. 2, 3, 4, 5, 6, 7 community leader/emergency managers/local authority). It means that "*the evacuation routes should be properly marked and well documented, safe/evacuation sites should be clearly identified*" (int. 1 community leader) and "*route/site require to be practiced through mock drills*" (int. 2 emergency managers/local authority).

7.3 Technical capacities

Warning systems are already in place in Chungthang, Mangan, Dikchu and Singtam, but they are not focused on GLOFs. The National Hydroelectric Power Corporation plans to set up an automatic water level Reporting system for 24X7 water level monitoring. Online data will be available and the same will be displayed in the dam control room. Real time data will be received which will alert dam downstream concerning real time water monitoring. Because at present, there is no GLOF EWS in the State, stakeholders like Army, ITBP, SDMA, DDMA, Teesta Urja Ltd, NHPC need to be trained on various technical aspects related to the operation and maintenance of instruments in addition to providing remote support for technical queries. Not only public but also private sector actors involved in the EWS installation (e.g., private companies installing equipment) may need targeted training.

7.3.1 GLOF monitoring system

EWS is considered a priority to increase disaster preparedness, while monitoring, warning and alarming are central elements of an EWS. Monitoring instruments and technical measurement tools must be set up to detect and monitor natural hazard processes so that timely warnings and alarms can be issued. Unfortunately, there are currently no sounds, no sensors, nor a sustainable data management system allowing real time communication and information on GLOF events in Sikkim. To this aim, it seems crucial (*i*) to identify exact places where technical devices could be installed (suggestions to use existing

Police/Army camps have been made because of existing human resources and facilities) as well as (*ii*) to improve their design so that electric black outs and robbery/vandalism will be avoided.

Suggestions have been also made to use satellite images for land observations, real time solar based cameras for water level control and radar based river level monitoring systems as those already set in place by the Central Water Commission. Further suggestions include the idea to install an EWS in Teesta Urja Control Room (see Section 6 for further details) or in the National Hydroelectric Power Corporation (NHPC) Control Rooms because they can ensure a 24hrsx7 days monitoring. Also, the Central Government could be asked to place a dedicated satellite for EWS purposes. The development of these technical capacities is also strongly related to the design of appropriate institutional and legal frameworks. More precisely it is essential to identify who could be liable in case of missed or false alarms and what will be the responsibilities of the public and especially the private sector actors involved in the EWS design and implementation (e.g., insurance companies, private companies installing the EWS equipment; see also Section 7.5.4).

7.4 Response and communication capacities

Warning/Alerts - usually received by the State government - are disseminated by SDMA/DDMA through State Emergency Operation Centre/ District Emergency Operation Centres. Response to any emergency -and GLOF is no exception- is done by activating the Incident Response System (IRS). The staff responsible for the dissemination of warnings at the emergency operation centres and the officials in charge of IRS need to understand the warning protocols and respond accordingly. Comprehensive training on warning protocols including Common Alerting Protocol (CAP) is required and provided for SEOC, DEOC and IRS staff.

7.4.1 GLOF siren/alarm

Several interviewees maintain that sirens are the most efficient and reliable ways of communicating about critical situations or GLOFs. Such alarming systems are already existing for dams ("*depending on the water level and subsequent discharge, different types/levels of sirens are sounded - once, twice, three times depending on severity level*"; int. 2 emergency managers/local authority) and could be adapted for GLOF events. Yet, some interviewees maintain that it will be extremely important to differentiate the currently existing dam water discharge sirens from the ones used for GLOF events (avoiding misunderstanding about the situation). However this topic remains open for discussion because other interviewees maintain instead that the system should be as simple as possible (i.e., only one siren). As electricity is highly unreliable/absent and even more in situations of disaster, another suggestion is that mikings remain indispensable. Finally, some community leaders fear that information about EWS, alarms or rumors (e.g., "*rumours of Dikchu Dam breakage during monsoon*" have been mentioned int. 3 community leader) may generate panic among the residents. Thus this fear makes them reluctant to inform the residents. This is another topic which remains open for further discussion.

7.4.2 Warning communication tools and strategy

Good communication is a key EWS component. Interviewees highlight that almost all the public are connected/actively interacting via cell phones, social media or similar (e.g., via Facebook News pages named Voice of Sikkim, Sikkim Chronicle, Sikkim Messenger). There is a high potential and added value in developing "*a mobile application with complete information on GLOF (e.g., real time river water level, emergency contacts, evacuation route, alarm system, etc.)*" (int. 2, 5, 7 emergency managers/local authority). A smartphone application-based/SMS-based warning system is considered particularly useful also to alert the downstream communities before any GLOF or other calamities. Interestingly, even if the majority of community leaders maintain that warning communication is effective, they have limited knowledge about warning communication practices, e.g., they do not know if a procedure of cancellation/all clear alarm exists, if false or missed alarms are frequent, etc. The same is not true for state government authorities or enterprises representatives that are well informed about existing warning levels and procedures. An overarching warning communication strategy is still considered an important aspect to include in the EWS development and in GLOF focused emergency, evacuation or disaster management plans. The strategy should include objectives and guiding principles for effective warning communication targeted for different audiences/targets. For example it is essential to ensure that migrant population and households are reached by warnings. It should also include a checklist and toolkit for local community leaders and disaster risk managers.

7.5 Legal and institutional capacities

7.5.1 EWS legal framework and responsibilities

Depending on the decisions that will be made concerning EWS technical aspects and capacities (e.g., monitoring and instrument decisions) responsibilities will have to be allocated and shared between the different actors involved. Not only State Government authorities but also enterprises - e.g., hydro power generation enterprises or insurance companies- may have to play an important role. Interviewees maintain that it is essential to deal with three types of responsibilities for the public and the private sector actors involved in EWS design and implementation: (1) financial responsibility for the costs of the EWS and maintenance; (2) system responsibility for assuring that the EWS is designed, installed and maintained; and (3) information responsibility for ensuring regular information, data transfer and timely warning. A major question during the EWS design process will be how these responsibilities could be shared, and the legal basis for this sharing, among experts, political representatives, and the communities.

7.5.2 Define appropriate responses against vandalism

The vast majority of consulted stakeholders admitted that there are low chances to avoid robbery/vandalism of technical devices installed for a warning system. The reasons behind vandalism acts can be different -e.g., economic profit, distrust and biases against those in charge of EWS installation, local intra- or inter-community conflicts, power dynamics- and need to be identified before the EWS is implemented. Several interviewees suggest that the authority in charge of operating and maintaining an EWS as well as sanctions in case of robbery/vandalism must be clearly identified.

7.5.3 Building constraints and regulation

One major issue in Sikkim is that "*constructions have come up randomly, and roads as well as foot-paths are narrowed*" (int. 3 community leader). Consequently, "*places are overcrowded with not much space/paths for evacuation*" (int. 4 public/community leader). Consequently, unplanned infrastructure had led (*i*) to further exposure of communities to GLOF events and (*ii*) inevitably affected resident's capacities to evacuate rapidly. In that respect, buildings and economic/urban development in highly hazardous areas need to be avoided and natural hazards need to be considered in the land-use planning. Moreover building constraints need to be respected more systematically.

7.5.4 Relocation

Numerous sites are highly exposed to GLOFs while protection structures are almost nonexistent along river banks. For example, "*Army settlements have been washed away in previous flood instances, so that relocation of such settlements needs to be considered*" (int. 8 emergency managers/local authority). Focus should also be on both upstream and downstream areas as downstream areas are equally vulnerable.

7.6 Economic capacities

To implement an EWS project, a proposal must be sent to the Govt. of India, State Govt., Land Revenue and Disaster Management Department, and other funding agencies like SDC, World Bank, etc. Moreover the State Disaster Response Fund has provisions for meeting expenditure on training and capacity building programs up to a specific limit and the NDMA has partnered with SSDMA for Reducing GLOF risk in Lhonak and Shako Cho Lakes in Sikkim. Despite the availability of economic resources for training and capacity building, a critical issue is related to the limited finance especially for (*i*) EWS maintenance at local level as well as for (*ii*) new mitigation measures/complementary to EWS (e.g., nature-based solutions). Interviewees suggest to develop a facility to improve knowledge and access to existing financial instruments for local authorities. Indeed small municipalities or villages with limited budget often have other priorities like investing in health and education services. Overall there is shared agreement that it is necessary to increase economic capacities, especially by providing resources at the local level.

7.7 Strengths and weaknesses evaluation

During the stakeholder consultations, strengths and weaknesses in the existing warning value chain have been evaluated. Information about training needs have also been collected. Table 2 provides a summary of the key inputs emerging from the stakeholder consultations.

Concerning capacities that need to be most developed, stakeholders mention especially preparedness, economic capacities (including improvement of EWS financing mechanisms, access to finance and knowledge of EWS finance options), and legal/institutional capacities (e.g., responsibility allocation for monitoring purposes). As opposed to emergency/disaster managers, community leaders emphasize also the importance of improving response/communication capacities.

8. Recommendations

In this knowledge-brief, we explored the capacities necessary for designing and implementing an EWS in Sikkim and for achieving a level of preparedness by each person or organization receiving a warning, that allows them to take actions to save their lives or reduce potential impacts. The analysis builds on the consultation with 83 stakeholders including targeted semi-structured interviews (face-to-face) and one workshop. The analysis reveals some problematic issues hindering EWS development, e.g. limited economic resources, low public participation, preparedness, risk awareness or knowledge but also institutional factors such as lack of GLOF focused disaster management plans, warning communi-

<table>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>• Robust DRM system
• Extensive DRM training and awareness raising initiatives
• Voluntary civil defense groups
• Reliable cooperation and communication with the Army
• Presence of the Army/Police in remote locations that can be used for EWS installations
• Active youth that can be involved in EWS related activities;</td><td>• Lack of GLOF focused disaster management/emergency/evacuation plans
• Limited options for evacuation routes
• Building constraints not respected or enforced
• Need for clear EWS accountability mechanisms and responsibility allocation
• Low public participation in DRM and EWS,especially of vulnerable social groups
• Lack of strategy targeted for the most vulnerable, e.g., migrants
• Communication blackouts in remote/not densely populated areas
• Limited GLOF media coverage
• Limited historical experience with GLOFs</td></tr>
<tr><th colspan="2">Training needs</th></tr>
<tr><td colspan="2">For communities
• Maintain GLOF community awareness raising initiatives (e.g., through educational programs,disaster management local groups or information campaigns using e.g., videos), GLOF mock drills/evacuation simulations/serious games
• Organize GLOF training targeted for migrants, schools and private companies
• Journalists training
For practitioners (e.g., emergency managers)
• Training toolkit should include information on how to understand warning systems, how to read early warning signal/report, how to interpret and disseminate the warning, methodology for collection, dissemination and actions related to warning value chain, responsibility allocation
• Guided visits/tours to already existing EWS, both within India and in other alpine contexts
• Training focused on EWS proposal development, including economic and institutional capacities</td></tr>
</table>

Table 2: Strengths, weaknesses, and training needs

cation strategy, limited engagement of the media sector, and unclear responsibility allocation for e.g., monitoring. To overcome these barriers, Table 3 provides a summary of recommendations based on the results presented in Section 7.

Type of capacity	Synergies with ongoing activities	Recommandations
Knowledge capacities		
Improve GLOF and EWS awareness	SDMA and DDMAs are organizing awareness campaigns using the SDRF capacity building fund	Exercises/ training sessions, target group oriented communication and awareness programs (especially targeting migrants/non locals, and renters); video/audio documentaries; meetings with communities; EWS scientific dissemination initiatives for risk and emergency managers; journalist focused initiatives/training to assure proper coverage of disasters by local media and awareness of new, potentially unprecedented threats; training of technical experts for EWS proposal development, including design, implementation and long-term maintenance
Promote stakeholder engagement		Understand EWS perceptions and anticipate conflicts before EWS installation; promote social mobilization to build EWS community's knowledge and trust; disseminate information; offer the opportunity to engage communities in the EWS design and implementation to generate local ownership
Preparedness capacities		
Develop GLOF emergency procedures	Strong synergies with standard emergency procedures	Inform about emergency procedures during Gram Sabha meetings; exercises, training sessions; seasonal and non-local worker's risk awareness raising; awareness program; civil defense volunteers as key resource to rely upon to increase community and individual preparedness
Design a GLOF disaster management and evacuation plan	Extensive volunteer and community training conducted by SDMA	Elaborate a GLOF focused disaster management plan and identify safe areas/evacuation plans; evacuation routes/sites differentiation; training/mock drills for evacuation; increase of available resources for preparedness at the household level, especially for migrants
Technical capacities		
Set up a GLOF surveillance network	High density polyethylene (HDPE) pipes have been installed for the siphoning of lake and for therefore lowering the level of water	Sound and sustainable surveillance network, communication (data transmission) and a data management system should be promoted; promote system redundancy to ensure no single point of failure in the system; promote importance of calibration and testing phase to limit false alarms, promote solar panels and batteries for energy generation and storage in case of blackouts
Response and communication capacities		
Develop warning communication tools		Mobile application with complete information on GLOF is an option, even if some interviewees doubt the reliability of the services immediately before and during disasters. Tools need to be available to the most vulnerable people (e.g., migrant workers)
Co-design a warning communication strategy	Synergies with simulations and other activities organized by community leaders and local authorities	A comprehensive warning communication strategy should also be developed, in combination with evacuation plans and emergency procedures
Legal and institutional capacities		
Define responsibilities	Building on existing DRM regulatory framework and guidelines	Financial, system and information responsibilities should be clearly identified; liability of public and private sector actors involved in EWS design, implementation and long-term maintenance.
Introduce building constraints		Building constraints enforcement to reduce the risk/improved land use planning
Encourage relocations		Permanent relocation (and compensation) of communities away from hazard-prone areas is becoming an important mitigation option for risk management
Define appropriate responses against vandalism		Protection measures (e.g., pile driving works, etc.) along river banks need to be built; Presence of police/army in remote sites; involvement of the community in the EWS implementation process; essential to highlight the EWS benefits for the community
Economic capacities		
Development of new finance mechanisms, also involving the private (e.g., insurance or tourism) sector in EWS implementation; facility to improve knowledge and access to existing financial instruments for local authorities		

Table 3: Recommendations

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Annexes

A Protocol

KNOWLEDGE CAPACITIES

Questions for	
All target groups	What are the areas that could be affected in case of a GLOF? What are the main causes of GLOFs in ___ selected hotspot area? What are the 3 elements at risk that you would like to protect from GLOF in ___ selected hotspot area? Do you think that GLOF risk in your area will change in the future and what would be the main driver of this change? Do you know of the existence of a Disaster Management Plan (DMP)? Do you have access to it? Are there any issues hindering the plan implementation? Has the DMP been revised since the latest events in the area? What would be the key components of a warning system for GLOF risk in ___ selected hotspot area? How can knowledge capacities for GLOF warning system development be improved? What knowledge/capacities are priority? What type of training is needed to increase your knowledge about preparing and responding to GLOF?

TECHNICAL CAPACITIES

Questions for	
Local authorities and emergency managers	Could technical devices (terrestrial installations) be installed on e.g., : i) outcrops; ii) infrastructures (e.g., bridges)? If yes, where (map, photos)? Are there existing installation sites that could be further developed and/or new installation sites that have been foreseen? If yes, can details (e.g., photos, reports, maps) be provided? Specific questions may include: What is the slope-exposition of those potential installation sites in ___ selected hotspot area? Are there already webcams in place in ___ selected hotspot area? If yes, who has access to these webcams and can new ones be installed? How good is the mobile network coverage (type of signal, provider)? Can we get electricity for technical installations? What are the options for (electric) energy generation during black outs? Do you think that technical devices installed (camera, sensors, installations) for a warning system may be stolen/damaged? How could robbery/vandalism be avoided? How would a closing of a road/evacuation of a settlement impact daily life? Does the capacity exist to install the technical components of such an EWS? Who could do that (company, institution, etc.)? More generally, how can technical capacities for GLOF warning system development be improved? What technical devices are a priority? What type of training (if any) is needed in relation to EWS technical capacities?

ECONOMIC CAPACITIES

Questions for	
Local authorities and emergency managers	Is funding available for EWS implementation and maintenance at local level? Who should be responsible for it? Is funding available for new mitigation measures/complementary to EWS? How can economic capacities for GLOF warning system development be improved? What capacities are a priority? What type of support to leverage or apply for funding would be needed?

PREPAREDNESS CAPACITIES

Questions for	
All target groups	Do you think that communities/residents have sufficient capacities to prepare and for natural calamities (GLOF)? Why? What capacities need to be developed? What are the main lessons learnt from recent/past events for preparedness? Are communities involved in the design of warning systems? Are there initiatives already in place (e.g., participatory community mapping or planning) to increase community preparedness and EWS knowledge? Are there any local conflicts (e.g., about funding, type of technical measures to be implemented, etc.) hindering the adoption of a warning system? How can preparedness capacities for GLOF warning system development be improved? What are the priorities? What type of training (if any) is needed to improve preparedness capacities?
Emergency managers	To our knowledge, there is an evacuation plan available for this location? Based on your experience, does the evacuation plan work effectively? Are escape routes and evacuation shelters known by all the population and accessible to everyone even during extreme GLOF activity? What should change?
Public/ community leaders	Have risk perception or preparedness studies been conducted in the community and what were the main learnings? Would citizen science initiatives (e.g. to monitor water levels) work?

COMMUNICATION CAPACITIES

Questions for	
All target groups	Did you receive a warning for a natural calamity in the past? If yes, which calamity? If so, who provided the warning? Through which channel (mobile phone, siren)? Did you understand it well? What can be improved? Are warnings generally understood by people and useful for them? What type of channels and messages are most effective? Is the local population connected/actively interacting via cell phones, social media or similar? If so, who is connected? What needs to change? Is any environmental monitoring implemented? If so, do thresholds for alarming exist (based on, for example, existing discharge values)? Do alerts (such as sirens, signal light, cell phone communication or oral information) cover the whole at-risk area? Does a procedure of cancellation/"all clear" alarm of the warning levels exist? Are false or missed alarms frequent? Are they decreasing response effectiveness? Overall, do you think that warning communication for natural calamities is effective? What should change? How can communication capacities for GLOF warning system development be improved? What capacities are priority? What type of training (if any) is needed to improve communication capacities?
Public/ community leaders	Is the information about an ongoing event received by all sub-groups (women, children, elderly, tourists, school teachers, etc.)? Are the warnings understood by all?

LEGAL AND INSTITUTIONAL CAPACITIES

Questions for	
Local authorities and emergency managers	Who/which authority would be in charge of operating and maintaining and EWS? Are there any legal issues related to evacuations? Are building constraints and land use related hazard zones respected? In case of a disaster, who validates the crisis situation and activates the emergency plan? Are the present institutional and legal frameworks working effectively? What needs to change? Who is responsible in case of false or missed alarms? Are there any economic consequences for local authorities in case of missed or false alarms? Who declares the end of the disaster and on the basis of what information/data? How can legal and institutional capacities for GLOF warning system development be improved? What type of training (if any) is needed to improve e.g. knowledge about legal and institutional capacities?

SUMMARY AND CONCLUSIONS

We have discussed the multiple capacities needed for effective functioning of EWS. To conclude:

- What are the main (max 3) strengths and weaknesses of present warning systems?
- What capacities need to be more developed in ____ selected hotspot areas?
- What training is most needed to develop these capacities?

B Minutes of the Consultation Workshop, Jul 12, 2021

Early Warning and Response System for Glacial Lake Outburst Floods for South Lhonak and Shakho Cho Lakes in Sikkim: Consultation Workshop

Date: 12 July 2021
Time: 11.00-13.00 IST/ (07.30-09.30 Swiss time)

The Swiss Agency for Development and Cooperation's (SDC) Global Programme Climate Change and Environment (GPCCE) India is supporting the operationalization of climate change adaptation actions in the mountain states of Uttarakhand, Sikkim and Kullu (Himachal Pradesh) through the "Strengthening Climate Change Adaptation in Himalayas (SCA-Himalayas)" project. As part of this program a stakeholder consultation workshop was organized for Sikkim focused on Glacial Lake Outburst Floods (GLOF) and Flood related natural hazards. About 60 participants attended the workshop.

Ms. Corinne Demenge, Head, SDC India welcomed the participants and introduced the Indo-Swiss bilateral cooperation in the areas of climate change mainstreaming, disaster risk management and water resources. She spoke about the climate change impacts in the Himalayan region, the instances of climate induced natural disasters in Uttarakhand, Himachal Pradesh and adjacent States and the resulting loss in human lives and infrastructure. The partnership has been going strong with Department of Science and Technology (DST), NDMA (National Disaster Mitigation Authority), Department of Water Resources and several state governments to address these issues.

<u>Key takeaways:</u> Strong institutional participation shows the importance attached to this project and partnership.

Mr. D.G. Shrestha, Director, DST Sikkim Government in his opening highlighted that several lakes (about 10) in this high mountain region have enhanced vulnerability due to climate change. He highlighted the earlier work on GLOF in the state and described the glacial retreat is clearly and scientifically established. He briefed the stakeholders on the background of the program in Sikkim. The State has identified 10 dangerous lakes, along with lakes Shako Cho and South Lhonak, Shako Cho being the most dangerous, with no outlet and presence of vulnerable villages in immediate downstream region. Sensors were installed in the glacial lake, measuring sudden rise or fall in water level, but it has not been successful. South Lhonak lake has formed in recent years, before that there was just the existence of South Lhonak Glacier and North Lhonak Glacier. With studies from National Remote Sensing Institute Hyderabad in 2012, triggered by an increase in size of the glacial lake, a working group was formed by MoEF&CC, to conduct bathymetric and electric resistivity survey to identify the status of the lake and develop an action plan for the same. Initial objectives of the study were to take up scientific mitigation measures and recommend sustainable and effective mitigation measures against GLOF in entire State. Key findings of the study were presented, which included presence of dead ice in the moraine dam based on the resistivity survey. This has led to constant monitoring, lake volume and depth measurements. The state has taken some control measures like lake siphoning, check dams, lake deepening and EWS to minimize GLOF risk in Sikkim. Increase in the size and volume of the lake and from 2010 to 2015 was depicted in the presentation. He stated that the state is augmenting its response mechanism and created a committee including Geological Survey of India (GSI) to examine these issues. Similarly a State Council of Climate Change has been constituted under Hon. Chief Minister to mainstream climate change issues in the state. He thanked SDC and consortium of Geotest-CTRAN and Universities for their support to the state in these areas.

<u>Key takeaways:</u> Planning with scientific basis and also mainstreaming disaster mitigation in climate change discourse. He also emphasized that the state would like to address all the lakes (as area of interest) not only one lake (South Lhonak) if the future vulnerability of Sikkim needs to be addressed.

Divya Kashyap, SDC, briefed about SCA- Himalayas project and its focus on integrating climate actions into national and sub national level planning implementation, with a broader objective to benefit the local community. Enhance the technical and institutional capacities of the State and national level govt., and institutions to mainstream climate resilient planning into their activities. SDC with support from NDMA, developed the national guidelines for the management of glacial hazards and risks (2016-19). As part of the interventions on disaster risk management for GLOF in Sikkim, SDC will also be working on Flash flood EWS in Parvati Valley, Himachal Pradesh, and Landslide EWS in Bhagirathi Valley, Uttarakhand. They will also look into communication protocols, capacity building of communities along with risk identification and EWS designing. GEOTEST led consortium, with University of Geneva, University of Zurich, GEOPRAEVENT and CTRAN will be supporting the process.

Key take away: program introduction for all the participants, especially the national level institutions who will be the key focal points for subsequent collaboration.

Christoph Haemmig, Geotest presented the project components and key outcomes expected, project consortium structure and the timeframe. The expert explained the technical component of an EWS. He has provided examples of EWS systems in Switzerland, Aletsch glacier, Plaine Morte glacier lakes and Grindelwald glacier lakes. He mentioned that as mountainous countries, India and Switzerland are both affected by increased glacier melt due to climate change and more frequent GLOF events. The experience of establishing EWS, decision support system and modelling will enhance the existing knowledge base in India.

Key take away: EWS implementation and modelling capability of the consortium as well as local level interface of CTRAN in climate action planning in all three states will come handy.

Simon Allen, University of Zurich shared the results of risk assessment and detailed hazard modeling of South Lhonak Lake in Sikkim. The approach to risk assessment has been according to the NDMA GLOF management guidelines. Importance of GLOF risk assessment has been discussed, along with their two-step approach of desk-based review and semi-automated assessment of GLOF risk to various sectors. The GLOF hazard, exposure, vulnerability components are considered for GLOF risk assessment, which can be replicated for all the lakes in the country. The study has combined multiple previous research studies, to identify the 10 high-priority lakes at state level. The results show a comprehensive and well-designed EWS will not only reduce the risk of the 2 respective lakes but also the surrounding high priority lakes. It also provides with a prediction of new lake formation over the century.

Key take away: GLOF risk assessment that takes into account hazard, exposure of settlement, infrastructures such as hydropower projects, roads, etc; the sensitivity of these elements to hazard and adaptive capacity in form of knowledge, technology and community involvement would be a replicable approach for similar assessment in the country. Based on this assessment, a well designed EWS will not only reduce risk and vulnerability of South Lhonak but also other lakes in the state.

Holger Frey, University of Zurich, presented a detailed hazard assessment and modelling in South Lhonak. He discussed on triggers of GLOFs (i) upstream mass movement, (ii) breach formation and (iii) large process chains and scenarios were made for all three processes. Evolution and characteristics of the South Lhonak lake shows its formation since 1990s and its further growth in future. Results of HEC-RAS modelling of breach formation at the Chungthang reservoir/dam was presented. A preliminary model result for large process chain, was also discussed, considering 3 scenarios. The potential triggers as mentioned are mass movements from upstream and breach formation, future lake expansions, increasing the probability of mass movement, large magnitude avalanches, topographic situations and floods reaching beyond Chungthang. Next steps include: refined modelling with bathymetric & high resolution DEM, elaboration of hazard maps, detailed risk assessment, detailed hazard assessment and modelling of Shako Cho, community surveys as well as focus group discussions in affected upstream settlements will also be needed.

Key take away: The ice core will melt, and breach intensity (flow depth and velocity) will increase risk to Chungthang. The modelling of large process chain will help in defining the worst-case scenario.

Anna Scolobig, University of Geneva discussed on the training needs and capacity building involved in the EWS design and management. The process includes, in depth assessment of EWS training, capacity building needs, development of training modules and generic guidelines. The need to develop a people centric EWS inclusive of risk knowledge, monitoring and warning services, dissemination & communication, and response capability. She also deliberated to get inputs on the strength and weakness of the present system.

Key takeaway: Community involvement in designing, interpreting and responding to alerts will involve significant capacity building at the local level (settlement and municipality), as they are the first responders.

Bhuwan Prakash Pradhan, Secretary, DST in his closing remark appreciated the support provided by SDC under SCA-Himalayas. He emphasized the vulnerability of the state nestled in high mountain region. Reflecting his early career in the region at the cutting edge he has seen these events up close and would appreciate any support to mitigate such risks.

Key takeaway: He found the technical discussion was extremely useful and would go a long way in developing robust mitigation measures, he concluded.

DISCUSSION

- **Dr. Rajesh Joshi (Regional Head, G.B Pant, Sikkim)**

Q1.
Whether the increase in the size of the lake over the years, is related to the increase in melting due to climate change or the snow melt?

Mr Frey agreed that, the future growth of lake is linked to glacial retreat which is in the rage of 0.8-1 Km.

Q2.
Projection on sediment flux due to possible breaching of lake, near the frontal side of glacier, the river flow contains lots of sediment flux, related to snow melt discharge and with high potentiality of breaching of such lakes, it may bring sediment in discharge, which is more dangerous than water to both the settlements and Hydropower projects.

The experts agreed to this observation and opined that the model takes these aspects into consideration.

Suggestion on Capacity building and awareness generation- Need to build community level institutions, which are highly affected during disasters and out of reach of government agencies.

Dr Ashok Singha, CTRAN agreed that, the involvement of the local community is part of the current DRM framework, and their input will help building a robust EWS and enhance their sustainability.

- **Dr. Ravinder Singh (Senior Consultant, NDMA**)

Q1.
Whether the already existing sediment load in the Teesta riverbed and its tributaries, being considered in the simulations and hydraulic modelling for EWS? As the existing sediment load will affect the flow height of the debris and flash flood.
Q2.
First modelling study for South Lhonak Lake and then Shako Cho Lake, but Shako Cho is more vulnerable and needs immediate attention. Whether simultaneous simulations will be considered for both the lakes.
Q3.
Whether designing of questionnaire for local understanding of people of Sikkim, to interact more with community representative or any target groups to be defined. Incorporation of local indigenous knowledge available, to design the EWS for local people.

Dr Frey explained that future lake expansion will increase mass movement impact but the topography will allow sufficient warning time for the community downstream.

Dr Ashok Singha mentioned that the questionnaires will be canvassed in Hindi and will also involve local community.

- **Dr. RK Sharma (DST, Sikkim)**

Suggestion: Glacial lake management plan can also have a component of Glacial and glacial lake protection regulation like in Chile and Argentina

- **Lalit Mohan (Sr. Geologist, GSI)**

Landslide susceptibility maps are available with GSI (NLSM Maps) which can be used for the study

- **Mr Phigu Bhutia (SSDMA)**

The state has undertaken several measures such as siphoning and he also suggested that there is large repository of indigenous knowledge available at the local level that need to be captured. During the discussion important points came up:

Strengths:

1. Community volunteer groups are alerting others, before the government bodies. EWS development should incorporate the same.
2. Incident Response System is present as part of current DRM protocol.
3. Training is provided to community volunteers through Aapda mitra scheme.
4. Stakeholders are aware of the impacts of climate change and EWS. ; local people got info earlier than dam authorities in Chamoli, so the local people need to be involved (appropriate sensors on ground and with proper training community can transfer information to local authorities).
5. Several Departments are working on the aspects on climate change mitigation.
6. SDMA has local level resources.
7. Institutions are aware and involved in the process.
8. Experience of GLOF mitigation is present.
9. Scientific awareness has increased over the years.
10. Community awareness has increased especially due to TV, mobile network and social media.

Weaknesses:

1. Alerts (the events happening in the past, and early warning sensors are not available, real time communication and information are lacking)
2. Sound and sustainable data management system are not present (RADAR based instruments)
3. Preparedness plans for impact mitigation
4. EWS are not yet present, earlier project did not materialise.

Dr Mustafa and Anna who facilitated the discussion concluded that a robust model linked with EWS technology and involvement of community volunteers as first responders are two key pillars, and the project should focus its attention on these two key aspects. Later the knowledge will be mainstreamed to policy and programming strategy.

Dr Dhiren, Director DST offered vote of thanks to all participants and for the overwhelming response.

C Minutes of the meeting to discuss final draft report on training and capacity building needs for EWS in Sikkim, Sep 30, 2022

Minutes of the Online Consultation on Knowledge Brief for GLOF EWS Training and Capacity Building for Strengthening Climate Change Adaptation in Himalayas (SCAHimalayas)

Date: 30 September 2022

Time: 02:00 pm - 03:00 pm

Summary of Key Discussion Points

1. Ms. Ridhima Sud welcomed the participants and requested stakeholders to share feedback on the knowledge brief on Glacial Lake Outburst Flood (GLOF) Early Warning System (EWS) training and capacity building.

2. Ms. Divya Sharma spoke on the SDC focus on local capacity building to replicate and upscale as well as to bring innovation at a policy level.

3. Mr. Dhiren Shrestha stated that size of South Lhonak lake has increased to almost 160 hectares and Shako Cho to 57 hectares. He added that after years of preparatory work, it is high time for tangible work in the field. He informed that DST Sikkim has recently conducted bathymetry studies of Shako Cho, which would be shared following due procedure. He further requested SDC to support DST and SSDMA for South Lhonak lake expedition for bathymetry studies of the Lake.

4. Ms. Anna Scolobig made a presentation on the Knowledge brief on training and capacity building needs prepared by Geotest. She spoke on the need for EWS, GLOF risk in South Lhonak lake and Shako Chho, EWS training and capacity building needs analysis – conceptual framework and methodology, key findings and recommendations.

5. Mr. Shrestha further requested SDC to facilitate an exposure visit-cum-training for Sikkim stakeholders to other sites where Disaster Risk Management and Water Risk Management have been successfully implemented.

6. Ms. Sharma informed that SDC is internally exploring options to provide exposure trip to Sikkim team.

7. Ms. Ada Lawrence requested Sikkim stakeholders for necessary feedback on the Knowledge brief in order to ensure a relevant and customized training and capacity building as per the local needs.

8. Mr. Prabhakar Rai stressed the need to bring together all local stakeholders into confidence. He added that the next field expedition is tentatively in April 2023, for which, requisite permissions and clearances need to be initiated. He requested for a concept note from SDC and DST so that SSDMA could pursue further on the subject with the State Government.

Key Action Points

9. SDC agreed to look into request raised by Mr. Shrestha for exposure visit-cum-training to stakeholders from Sikkim.

10. SDC to share final report with State Government for approval/endorsement following which, State Government and SDC will jointly publish the report for ready reference of all stakeholders.

D List of the consulted stakeholders

INCEPTION WORKSHOP PARTICIPANTS

1. Ms. Corinne Demenge, Head, Swiss Agency for Development and Cooperation, New Delhi, India;
2. Mr. Bhuwan Prakash Pradhan, Secretary, Department of Science and Technology, Government of Sikkim;
3. Mr. DG Shrestha, Director, Department of Science and Technology, Government of Sikkim;
4. Mr. Phigu Tshering Bhutia, Additional Director, Sikkim State Disaster Management Authority (SSDMA);
5. Mr. M Bharani Kumar, IAS, District Collector, South, District Disaster Management Authority, South;
6. Ms. Urmila Thapa, Joint Director (E&SC), Forest Department;
7. Dr. Ravinder Singh, Senior Consultant (Landslide & Avalanche), National Disaster Management Authority;
8. Mr. Karma D Wajalingpa, Deputy Director, District Disaster Management Authority, North;
9. Mr. Arpan Chettri, QRT, District Disaster Management Authority, North;
10. Mr. Sonam W Lepcha, Deputy Director, District Disaster Management Authority, East;
11. Mr. Subash Ghimirey, SDM Chungthang, District Disaster Management Authority, North;
12. Mr. Tilak Gajmer, Director, Agriculture Department;
13. Dr. Sanjay M. Gajmer, Director, Animal Husbandry & Veterinary Services Department;
14. Dr. Subash Dhakal, Assistant Director, Rural Development Department;
15. Ms. Monika Rai, Under Secretary, Food & Civil Supplies Department;
16. Mr. Kunzang G. Bhutia, Chief Instructor-cum-Assistant Director (Adventure Sports), Department of Sports & Youth Affairs;
17. Mr. N P Sharma, Asst. Scientific Officer, Department of Science and Technology;
18. Mr. Pranay Pradhan, Senior RA, Department of Science and Technology;
19. Mr. RK Sharma, Senior RA, Department of Science and Technology;
20. Lt Col RA Dattatraya, Second in Command, 106 Engineer Regiment, 17 Mtn Div.;
21. Mr. Chandan Singh Bhandari, Commandant, 13Btn, ITBP;
22. 86 RCC (GREF), GREF, Shri Rajat Agarwal, Asst. Executive Engineer, GREF 87 RCC;
23. HQ C E (P) SWASTIK, Border Roads Organisation, Brig SP Singh, Chief Engineer;
24. Mr. Mathew Rai, Fire Station Officer, Headquarter, Fire & Emergency Services, Firemsgangtok;
25. Mr. Saurav Tshering Lepcha, Superintending Engineer (N/E), Buildings Department;
26. Ms. Nordem Pintso, Assistant Engineer (Project), Tourism & Civil Aviation Department;
27. Mr. Laxmi N. Nepal, Joint Registrar, Head Office, Cooperation Department;

28. Mr. Shashank Bhushan, Executive Engineer, Executive Engineer;
29. Mr. Lalit Mohan, Senior Geologist, Geological Survey of India;
30. Dr. Rajesh Joshi, Regional Head, G.B Pant Institute;
31. Dr. Rakesh Ranjan, Assistant Professor, Geology Division, Sikkim University;
32. Mr. Jitendra Kumar, Chief Engineer (Electrical), Teesta V;
33. Mr. S P Mukherjee, Chief Executive Officer, LTHPL Teesta-VI, NHPC;
34. Mr. Manoj Lakra, General Manager (Civil), LTHPL Teesta-VI, NHPC;
35. Mr. B R Godara, Dy. General Manager (Geology), LTHPL Teesta-VI, NHPC;
36. Dr. Manohar Arora, Scientist ’E’, National Institute of Hydrology, Roorkee;
37. Dr A.K. Lohani, Scientist ’G’, National Institute of Hydrology, Roorkee;
38. Dr. Ashok Singha, Managing Director, CTRAN Consulting, Bhubaneswar-751014, Orissa;
39. Mr. Chandrakanta Ojha, Local expert, CTRAN Consulting, Bhubaneswar-751014, Orissa, India;
40. Ms. Ishani Mohanty, Consultant, CTRAN Consulting, Bhubaneswar-751014, Orissa, India;
41. Mr. Barendra Sahoo, Associate Vice President, CTRAN Consulting, Bhubaneswar-751014, Orissa, India;
42. Mr. Dev Kumar Dutta, Associate Consultant, CTRAN Consulting, Bhubaneswar-751014, Orissa, India;
43. Ms. Divya Kashyap, Senior Thematic Advisor, Swiss Agency for Development and Cooperation, New Delhi, India;
44. Mr. Mustafa Ali Khan, Team Leader, SCA Himalayas, Swiss Agency for Development and Cooperation, New Delhi, India;
45. Mr. Bhupendra Bhaisora, Technical Expert, DRM, SCA Himalayas;
46. Ms. Ada Lawrence, Technical Expert, DRM, SCA Himalayas;
47. Mr. Ghanashyam Kharel, Technical Expert, WRM, SCA Himalayas;
48. Mr. Suresh Betapudi, Technical Lead, DRM, SCA Himalayas;

ONLINE MEETING FOR KNOWLEDGE BRIEF

1. Ms. Divya Sharma, Deputy Head of Cooperation, SDC India
2. Mr. D.G. Shrestha, Director DST, Government of Sikkim
3. Dr. N.P Sharma, Scientific Officer DST, Government of Sikkim
4. Dr. R.K Sharma, Senior Research Assistant DST, Government of Sikkim
5. Mr. Prabhakar Rai, Director SSDMA, Government of Sikkim
6. Dr. Pema Lachungpa, Deputy General Manager, Teesta Urja Ltd
7. Mr. Jayanta Chowdhury, Manager, Teesta Urja Ltd

8. Mr. Pemzang Tenzing, Private Consultant, DDMA Mangan
9. Ms. Ridhima Sud, Team Leader, SCA-Himalayas
10. Mr. Suresh Betapudi, Technical Lead DRM, SCA-Himalayas
11. Mr. Ghanashyam Kharel, Technical Expert WRM, SCA-Himalayas
12. Ms. Ada Lawrence, Technical Expert DRM, SCA-Himalayas

INTERVIEWEES

1. Mr. Lhendup Lepcha, Ex-Panchayat President, Chungthang;
2. Mrs. Radha Pradhan, Vice President, Rangpo Nagar Panchayat;
3. Miss Larishna Tamang, Councillor, Rangpo Nagar Panchayat;
4. Mrs. Sanju Manger, Councillor, Rangpo Nagar Panchayat;
5. Mr. Pinku Kumar Prasad, Councillor, Rangpo Nagar Panchayat;
6. Mr. Suresh Kumar Tamang, President, Singtam Nagar Panchayat;
7. Ms. Bindhya Subba , Vice President, Singtam Nagar Panchayat;
8. Ms. Yad Kumari Kami,Councillor, Singtam Nagar Panchayat;
9. Mr. Mukesh Agarwal,Councillor, Singtam Nagar Panchayat;
10. Mr. Kishore Chettri,Councillor, Singtam Nagar Panchayat;
11. Mr. Tseten Lepcha, Public, Chungthang;
12. Dr. A.B Karki, District Magistrate, Mangan;
13. Mr. Karma D Wajalingpa, Deputy Director Disaster Management, Mangan;
14. Dr. Ajay Kumar Jha, Senior Manager (Environment), National Hydroelectric Power Corporation (NHPC), Balutar;
15. Mr. S.D Bhutia, SeniorManager (Civil), Teesta V Power Station, NHPC, Balutar;
16. Mr. Subhash Ghimirey, Sub Divsional Magistrate, Chungthang;
17. Mr. Milan Rai,Sub Divsional Magistrate, Rangpo;
18. Mr. B.D Kumar, Executive Director-cum-Site Head, Teesta Urja Limited, Chungthang;
19. Mr. Naveen Kumar, Chief General Manager, Teesta Urja Limited, Chungthang;
20. Mr. Jawhar Singh, General Manager (Security), Teesta Urja Limited, Chungthang;
21. Dr. Pema Tenzing Bhutia, Deputy General Manager, Teesta Urja Limited, Chungthang;
22. Mr. Pemzang Tenzing, Public, Mangan;