Glacier Lake Outburst Floods: Loss of Life and Infrastructure in Sikkim, India in October 2023 is a Wakeup Call across the Himalayas and Beyond

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In the wee hours of 4th October 2023, Rasila* frantically banged on the door to wake her family up but the water came gushing in and propelled her to run up to the road where she stood helpless and in utter shock watching the water, reported to be 15-20 feet high downstream, wash her house and family away. Nirmal* hurriedly brought his wife and children to the car and rushed back to the house to get his father. But by the time he came back his family was washed away and he could hear them screaming for help. He recounts this with tears saying that he stood there helpless in the darkness. In addition to Rasila and Nirmal's grieving accounts, there are numerous heart-wrenching records of the survivors of the recent deluge on the Teesta River in Sikkim and other downstream areas in the Northeastern part of India and across the border in Bangladesh.

(*Names changed for anonymity).

Fig. 1. Teesta III Hydropower Plant, Sikkim, before and after the Oct. 4, 2023 flood. Credit: https://sandrp.in/tag/teesta/

The Teesta is a tributary of the Brahmaputra River, which has left massive destruction in Sikkim. The Government of Sikkim as of November 8, 2023 has reported 42 human lives lost, over 77 missing, 88,400 as the population affected, 5,665 evacuated, 2,563 people rescued, and 4 relief camps are still operational. Additionally, 16 bridges were washed away and the impacts of this flood were compounded by the sudden release of 5.08 million m^3 (2,000 olympic swimming pools) of water from Sikkim's largest 1200 MW Teesta III hydroelectric dam at Chungthang, which failed catastrophically (Fig. 1).

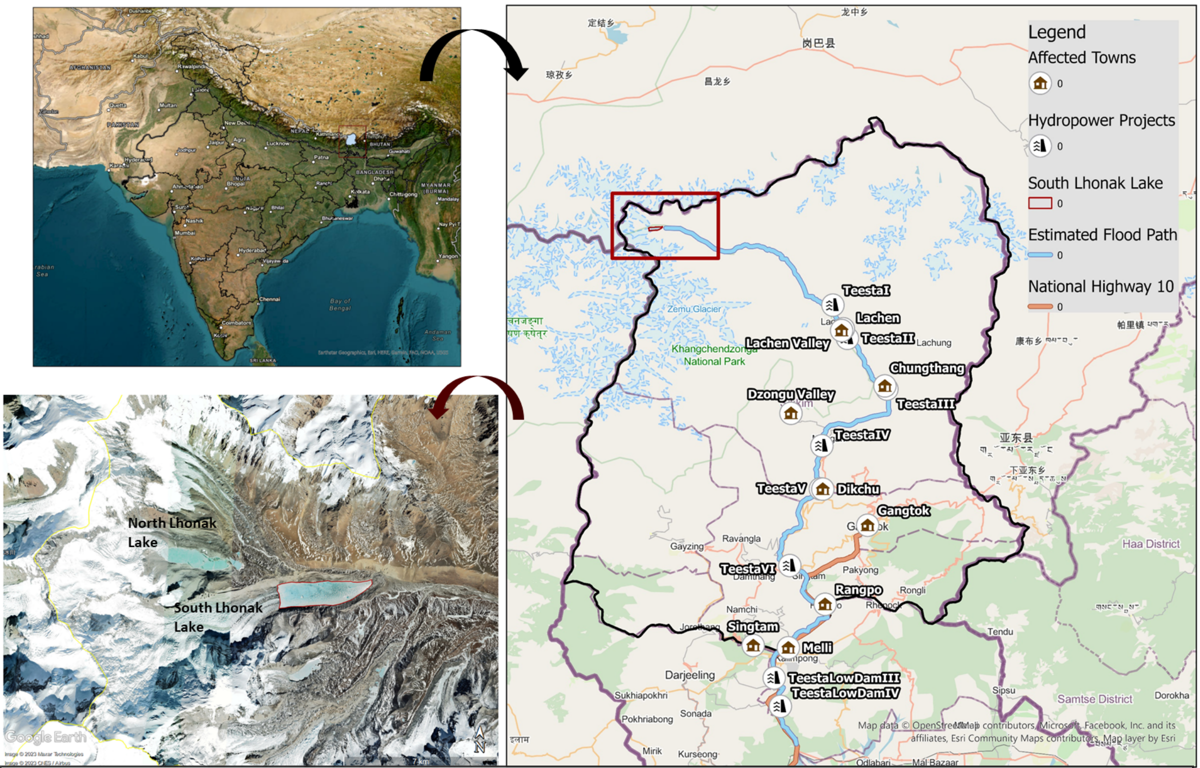

Fig 2. Map of Sikkim, South Lhonak Lake, overview of flood affected areas and selected hydropower projects

The Teesta, arrested at several points due to cascade hydropower development, reclaimed its free flow carrying boulders and debris that have left unprecedented and unimaginable impacts on the downstream areas (Fig 3a). The National Highway 10, the only connecting link of Sikkim to the rest of India has been devoured, sewerage treatment plants, water and electricity supply infrastructure has been severely affected (Fig 3b). Within the state there are places which have been completely cut off, thus further marginalizing some affected citizens.

Fig. 3a. Aerial view of the affected area and Teesta River in full fury. Courtesy: Praveen Chettri

Fig 3b. Road connectivity severely affected at the Rithcu Village in North Sikkim. Courtesy: Dupjang Lepcha, ATREE

What is a Glacial Lake Outburst Flood?

The sudden release of water from a lake situated at the terminus or surface of a glacier is termed a Glacier Lake Outburst Flood (GLOF). Hours after the devastating flood inundated Chungthang, the Indian Space Research Organizations (ISRO) released the map of South Lhonak lake and its reduced area, confirming the suspicion of a GLOF. Moving glaciers erode the bottom topography and create depressions below the glacier surface. When the glacier retreats, the meltwater accumulates in this depression forming a moraine dammed lake. Climate change-driven glacier retreats have increased the number and area of glacier lakes throughout the Himalayan range. The state of Sikkim has around 644 glacier lakes covering an area of 29.70 km^2 out of which 108 are larger than 0.05 km^2 based on the satellite data of 2014. This inventory indicates that most of the large glacier lakes are situated at the high altitude of 5000 to 5500 m, out of which 11 lakes are greater than 0.5 km^2 situated in areas where regular monitoring and installing mitigation strategies are difficult.

Drivers of the Catastrophic South Lhonak GLOF

The South Lhonak lake is among the largest high-altitude glacier lakes in Sikkim and has been the poster child of potential GLOF disasters in the Himalayas. The lake area increased from 0.2 km^2 in 1976 to 1.67 km^2 in 2023. The current volume of water stored in the lake (prior to the flood) is estimated as 65.8 million m^3 with a predicted future volume of 114.8 million m^3. The GLOF potential of South Lhonak lake had been long identified by researchers and notified to the government authority. It was noted that the lake is susceptible to GLOF due to ice-calving from glacier snout, failure of moraine, excessive precipitation, earthquake, snow avalanche or landslide into the lake, and overflow from North Lhonak lake. Recent satellite imagery has revealed that the GLOF was indeed triggered by a landslide of waterlogged lateral moraine into the lake compounded with the heavy rainfall (Fig. 4). The rapid movement of the moraine caused the overflow of water from the lake which reached the downstream areas rapidly within minutes of the disaster.

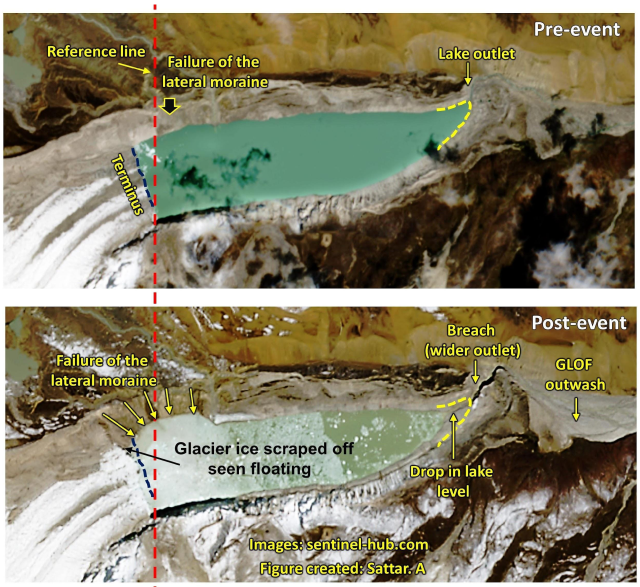

Fig 4. Pre and post event satellite imagery of South Lhonak lake showing the possible trigger for GLOF. Courtesy: Ashim Sattar

Anthropogenic role in GLOF formation, response, and remediation

A common question often asked after a disastrous flood event such as this is how certain are we of the anthropogenic role. Could this have been averted? Could the impacts be lowered? The destabilization of the moraine and overflow can be closely tied to rapid glacier retreat which is an indication of its link to anthropogenic climate warming. Further, the Government of Sikkim had undertaken a long-term mitigation strategy to reduce the hazard potential of South Lhonak lake by reducing the water level from the lake using siphoning and control widening of the discharge channel in 2016 (Fig. 5). The process of an early warning system has been in its early stages and was expected to be completed in a year. This early warning system at Lhonak and Shako Cho lakes in Sikkim, were to be among the first in India for GLOFs. Thus, the understanding of the looming GLOF threat was actively discussed not just by the scientific community but also in the government agencies. However, simply understanding these hazards is not enough, they need to be accounted for in the development and planning decisions which is where the major lack of the mitigation strategy was identified. The construction of the hydroelectric projects in disaster prone areas also increases human settlement which adds more local population and infrastructure vulnerable to the flood risk (Fig. 6). Although such disasters occur due to natural triggers (indirectly connected to anthropogenic activity), they cannot be decoupled from human activity and development downstream which play a significant role in increasing the damage from the hazards. At present, scientists are concerned about the cascading effect of water overflow from the upstream North Lhonak lake into South Lhonak which could take place if the excessive rainfall persists which would create far-reaching damage in Sikkim and downstream in the State of West Bengal and Bangladesh (Fig. 2).

Fig 5. Siphoning water to reduce the lake levels at the South Lhonak Lake. Courtesy: Sikkim Government Technical Report

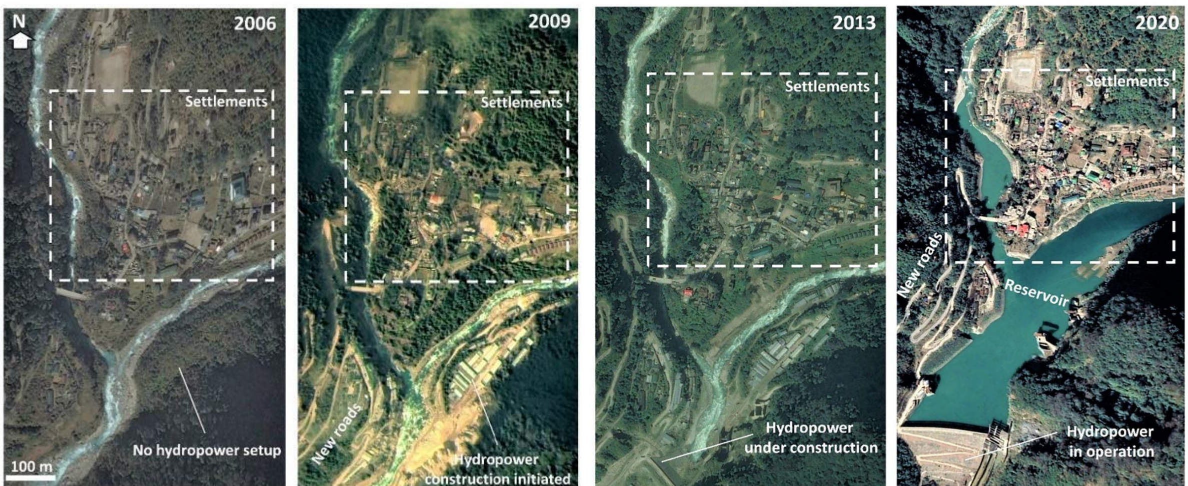

Fig. 6. Increase in settlement in and around Chungthang following the construction of Teesta III Hydropower project. Courtesy: Ashim Sattar

Resilience of local communities and pan-Himalayan implications

The local communities, activists, scholars, scientists, and members of the civil society have been quick to respond to the crisis. The anti-dam sentiments have grown immensely, and the glaring lack of mountain-specific policies addressing fragile ecosystems of the Himalayan region have been pointed out (Fig. 7a). It is essential for both the power, water, and infrastructure planners and government agencies to accept that the carrying capacity of the small state of Sikkim, which consumes only around 400 MW of energy but was generating 2,300 MW, has been far exceeded. The rescue operations and relief measures are underway. The local communities building ziplines to transport food and materials to the cut off villages show that the mountain communities have time and again proven their resilience (Fig. 7b). It is time for them to be heard and give breathing space to the small state now more than ever.

Fig. 7a. The destroyed Teesta Stage III dam at Chungthang. Courtesy: Anonymous

Fig. 7b. Women trying to salvage their money (bank notes recovered from their lost homes) at Rangpoo. Courtesy: Praveen Chettri

With similar hazards that have struck the Western Himalayas earlier this year, it has become a wakeup call not just for Sikkim, but for all Himalayan states in India, and beyond. National agencies and international institutions must integrate scientific knowledge into development decisions. The combined impacts of changes in climatic and socio-economic conditions are likely to increase the frequency of natural hazards in the Himalayas, increasingly putting local population and infrastructure at risk of destruction.

This calls for us to address complex social-ecological interactions to increase the disaster resilience of local communities through adaptive and responsive planning and operations. Steps in this direction include:

- Provide public access to data, information, and future disaster predictions
- Account for deep uncertainties
- Include local interests in planning processes and disaster response
- Formally account for, and fund, contingency measures
- Share lessons learned broadly, take up lessons learned in other locations

~ A blog from the Environmental Policy Goddard Chair Group at Penn State University,
https://ecosystems.psu.edu/research/labs/environmental-policy-goddard-chair-group