Guarding Against Glacial Lake Outburst Floods

This editorial is based on **"The message from Sikkim: Heed the water's warning"** which was published in The Indian Express on 16/10/2023. It talks about the recent glacial lake outburst flood (GLOF) in Sikkim that caused massive damage and loss of lives. It also discusses the causes and consequences of such events, and the possible solutions to prevent or mitigate them.

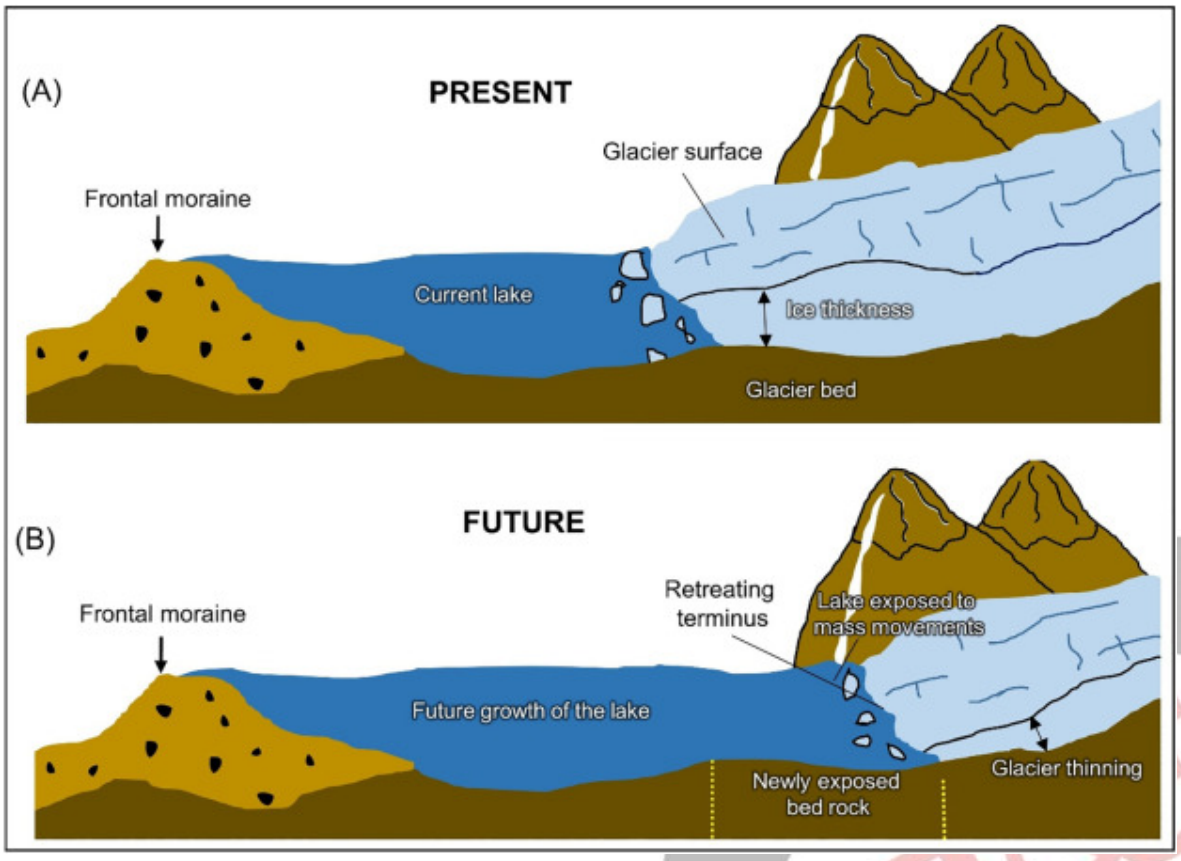
For Prelims: Glacial lakes, **Glacial Lake Outburst Flood (GLOF), Glacial Lake Formation, Earthquakes, Geological Survey of India, National Remote Sensing Centre (NRSC), Synthetic-Aperture Radar**

For Mains: Glacial Lake Outburst Flood - Reasons, Impacts, **NDMA Guidelines** and Way Forward

During the early hours of October 4, the southern bank of South Lhonak Lake in Sikkim breached, releasing a powerful mixture of icy water and debris. The resulting floods devastated the Chungthang Dam, NHPC hydropower projects, and the region's infrastructure. Tragically, more than 35 lives were lost, 14 bridges disappeared, 1,320 houses suffered severe damage, and essential utilities were disrupted. The destruction extended to highways in North Sikkim, Gangtok, Pakyong, and Namchi districts, including sections of National Highway 10, a crucial link to the rest of India.

What is GLOF?

- **Glacial lakes,** like the South Lhonak Lake, are **large bodies of water that sit in front of, on top of, or beneath a melting glacier.**
  - Alternatively, Glacial lakes are **formed near the snout of glaciers** when meltwater accumulates.
- As they **grow larger, they become more dangerous** because glacial lakes are mostly dammed by unstable ice or sediment composed of loose rock and debris.
- In case the boundary around them breaks, huge amounts of water rush down the side of the mountains, which could cause flooding in the downstream areas.
  - This is called glacial lake outburst floods or GLOF.
- GLOF can be triggered by several reasons, including **earthquakes,** extremely heavy rains and ice avalanches.



What are the Reasons behind the Glacial Lake Outburst Flood?

- **Climate Change and Glacier Melting:** The increased **warming of the troposphere** is a direct consequence of **climate change.** This warming has led to the accelerated melting of glaciers in various parts of the world.
    - As glaciers melt, they release water, which can accumulate in depressions, forming lakes. These glacial lakes are temporary and can pose significant hazards.
- **Glacier Retreat:** As glaciers melt and retreat due to rising temperatures, they leave behind depressions or basins. **These depressions can fill with meltwater and ice, forming glacial lakes. When these lakes become too large, the pressure on the damming material increases,** increasing the risk of a GLOF.
- **Glacier Surge:** Some glaciers can experience surges, which are periods of rapid advance and retreat. **During a surge, a glacier can dam up meltwater, creating a temporary glacial lake.** When the surge ends, the dam can breach, causing a GLOF.
- **High Vulnerability Quotient:** The **embankments of these lakes consist of loose deposits of glacier moraine, rocks, boulders, soil and ice.** Since these embankments are not properly compacted, they have a high vulnerability quotient.
- **Avalanche or Landslide:** Avalanches, rockfalls, or landslides can impact the damming material, causing it to weaken or collapse and allowing the lake's water to escape suddenly.
- **Earthquakes:** Seismic activity can **trigger GLOFs by fracturing or weakening the damming material.** In some cases, earthquakes can also dislodge ice and debris into the lake, leading to a rapid rise in water levels and subsequent flooding.
- **Volcanic Activity: Volcanic eruptions can lead to the melting of glaciers** and the release of massive amounts of water, which can cause a GLOF.
- **Human Activities:** Human activities, such as **mining, construction, or deforestation in the vicinity of glacial lakes,** can destabilize the natural barriers and increase the risk of a GLOF.
- **Artificial Lake Formation:** Artificial glacial lakes can **form as a result of construction projects, such as hydropower dams or mining activities**. Poorly designed infrastructure and maintenance can lead to a higher risk of GLOFs.

What are the Impacts of Glacial Lake Outburst Floods?

- **Loss of Life and Property:** GLOFs can kill people, destroy houses, bridges, roads, forests, and farmland, as well as livestock and crops.
    - For example, a GLOF in Sikkim, India, in October 2023 killed at least 18 people and left more than 150 missing. Another GLOF in Uttarakhand, India, in June 2013 killed more than 5,000 people and damaged several hydropower projects.
- **Disruption of Livelihoods:** GLOFs can **affect the livelihoods of the local communities for long periods, by reducing their access to resources,** markets, services, and opportunities. GLOFs can also damage the tourism industry, which is a major source of income for many mountain regions.
- **Damage to Infrastructure and Environment:** GLOFs can damage or **destroy hydropower plants, which are important for providing electricity** and reducing greenhouse gas emissions. GLOFs can also alter the landscape, erode the soil, increase the sediment load in the rivers, and affect the water quality and availability.
- **Trans-boundary Impact:** GLOFs can also **affect the downstream areas far from the glaciated headwaters where the threats originate.**
    - For example, trans-national GLOFs originating in the upper **Satluj River Basin** (China) are a threat to downstream areas of eastern Himachal Pradesh.

How Vulnerable is India to GLOFs?

- **ISRO's Glacial Lake Atlas:** The **ISRO's National Remote Sensing Centre (NRSC)** released a glacial lake atlas for the Himalayan River Basins. This atlas was prepared using images acquired by the **RESOURCESAT-2 satellite** during 2016-17 and identified over 28,000 glacial lakes larger than 0.25 hectares.
- **Sikkim:** The Sikkim State Disaster Management Authority has identified more than 300 glacial lakes in the state. Out of these, 10 have been classified as vulnerable to outburst floods. However, NRSC's assessment has identified a larger number, 733 glacial lakes in Sikkim.
- **Uttarakhand:** The **Geological Survey of India** has found that 13 out of the 486 glacial lakes in Uttarakhand are vulnerable to GLOFs.
- **Jammu and Kashmir**: A 2021 study led by Delhi University scientist reported that Jammu and Kashmir has the highest number of vulnerable glacial lakes, followed by Arunachal Pradesh and Sikkim. This indicates that the threat of GLOFs is not limited to a single region but is widespread in the Himalayan region.

NDMA Guidelines for Management of GLOFs

- **Identifying Potentially Dangerous Lakes:**
    - **Recognizing potentially dangerous lakes involves a multidisciplinary approach.** Field observations, historical records, and analyzing geomorphological and geotechnical characteristics can help identify high-risk areas.
    - This information can be used to prioritize monitoring and risk-reduction efforts.
- **Use of Technology:**
    - The **use of Synthetic-Aperture Radar imagery** can greatly enhance early warning systems.
    - This technology can detect changes in water bodies, monitor glacier movements, and identify new lake formations, especially during monsoon seasons.
    - **Remote monitoring from space** can provide a broader perspective, helping to track changes in lake conditions over time.
- **Channeling Potential Floods:**
    - Managing lakes structurally is an important aspect of risk reduction. **Techniques such as controlled breaching, pumping out water, and tunnel construction** can help lower the water volume, reducing the risk of a GLOF.
    - These methods should be well-planned and executed to minimize downstream impacts.
- **Uniform Codes for Construction Activity:**
    - The **development of uniform construction codes** for infrastructure and land use planning in GLOF-prone areas is essential. These **codes should consider the geological and hydrological risks** and incorporate measures to mitigate these risks in construction projects.
- **Enhancing Early Warning Systems (EWS):**

    - Early warning systems are critical for disaster preparedness. **Implementing sensor- and monitoring-based technical systems for GLOF early warning is vital,** as it can provide timely information to at-risk communities.
    - Expanding the coverage of such systems is essential, especially in regions prone to GLOFs.
- **Training Local Manpower:**
    - Local communities play a crucial role in disaster response and preparedness. **Training local personnel can help in the rapid and effective response to GLOFs.**
    - These trained individuals **can perform search and rescue operations, assist in setting up emergency shelters, and distribute relief supplies,** which are often the first line of defense in disaster situations.
- **Comprehensive Alarm Systems:**
    - **Modern communication technology,** such as cell phones and smartphones, can complement or replace traditional alarming infrastructure.
    - Utilizing these technologies for **mass notification systems** can reach a wider audience and provide timely alerts in case of impending disasters.

What Measures can be taken to Mitigate GLOF Disaster?

- **Monitoring and Data Collection:** Intense monitoring of meteorological events **near the snout of vulnerable glacier lakes is an urgent necessity.** Data should be gathered at observatories and communicated to a centralized office. It should be processed in real-time to forecast the behavior of glacial lakes and alert people.
    - Water levels in rivers downstream of vulnerable lakes should also be monitored continuously.
- **Use of Technology:** A nationwide programme to regularly monitor vulnerable glacier lakes by satellites and drones should be initiated. This technology can complement ground-based observatories and enhance the overall understanding and prediction of GLOFs.
- **Revised Safety Standards:** Given the increased threats from GLOFs, **safety standards for infrastructure projects in mountainous areas should be revised**. This includes projects like dams, bridges, and highways. Quality control measures should be stringent to ensure the safety of such projects.
- **Regulation of Construction:** Infrastructure projects in mountains — **dams, bridges and highways — must be subjected to stringent quality control measures.** GLOFs and other floods in mountainous regions have shown that buildings constructed close to rivers were the first and the worst sufferers.
    - Construction close to rivers should, therefore, be carefully regulated.
- **Scientific Research:** Scientific **studies on glaciers in the country must be scaled up.** Climate projections indicate that glaciers are receding in the Himalayan region. This means that new lakes are likely to form and the existing ones could expand.
    - **Glaciers are among the best indicators of climate change.**
        - It is, therefore, **necessary to understand how these ice bodies respond to climate change in the different Himalayan zones** — among the most data-scarce regions in the country.
- **Comprehensive Risk Assessment:** The Himalayan region requires **a comprehensive risk assessment that accounts for projected temperature rise, changes in precipitation patterns, and land-use/cover changes.** This assessment should inform disaster risk-reduction strategies.
- **Balancing Hydropower Development:** The Northeast has a key place in the hydel power push of successive governments at the Centre. The Chungthang Dam is a part of the 1,200 MW Teesta Stage 3 Hydroelectric Project.
    - The **government claims that such projects are climate-friendly** because of their low emissions intensity.
    - Ecologists, however, **caution against the adverse effects of dam construction** — it increases the volatility of rocks in the **Himalayan region.**
    - The sikkim disaster is a warning to take such caveats seriously and install robust safety mechanisms.

Drishti Mains Question:

Discuss the factors contributing to the vulnerability of the Himalayan region to Glacial Lake Outburst Floods (GLOFs) and the measures that can be taken to mitigate the risks associated with GLOFs

UPSC Civil Services Examination, Previous Year Questions (PYQs)

Q. Dam failures are always catastrophic, especially on the downstream side, resulting in a colossal loss of life and property. Analyze the various causes of dam failures. Give two examples of large dam failures. **(2023)**