India’s Preparedness Against GLOFs

For Prelims: National Disaster Management Authority (NDMA), Glacial Lake Outburst Flood (GLOFs), Landslides, Glacial Lake, Flash Floods, International Centre for Integrated Mountain Development (ICIMOD)

For Mains: Impact of Climate Change on Glacial Lakes and their Consequences.

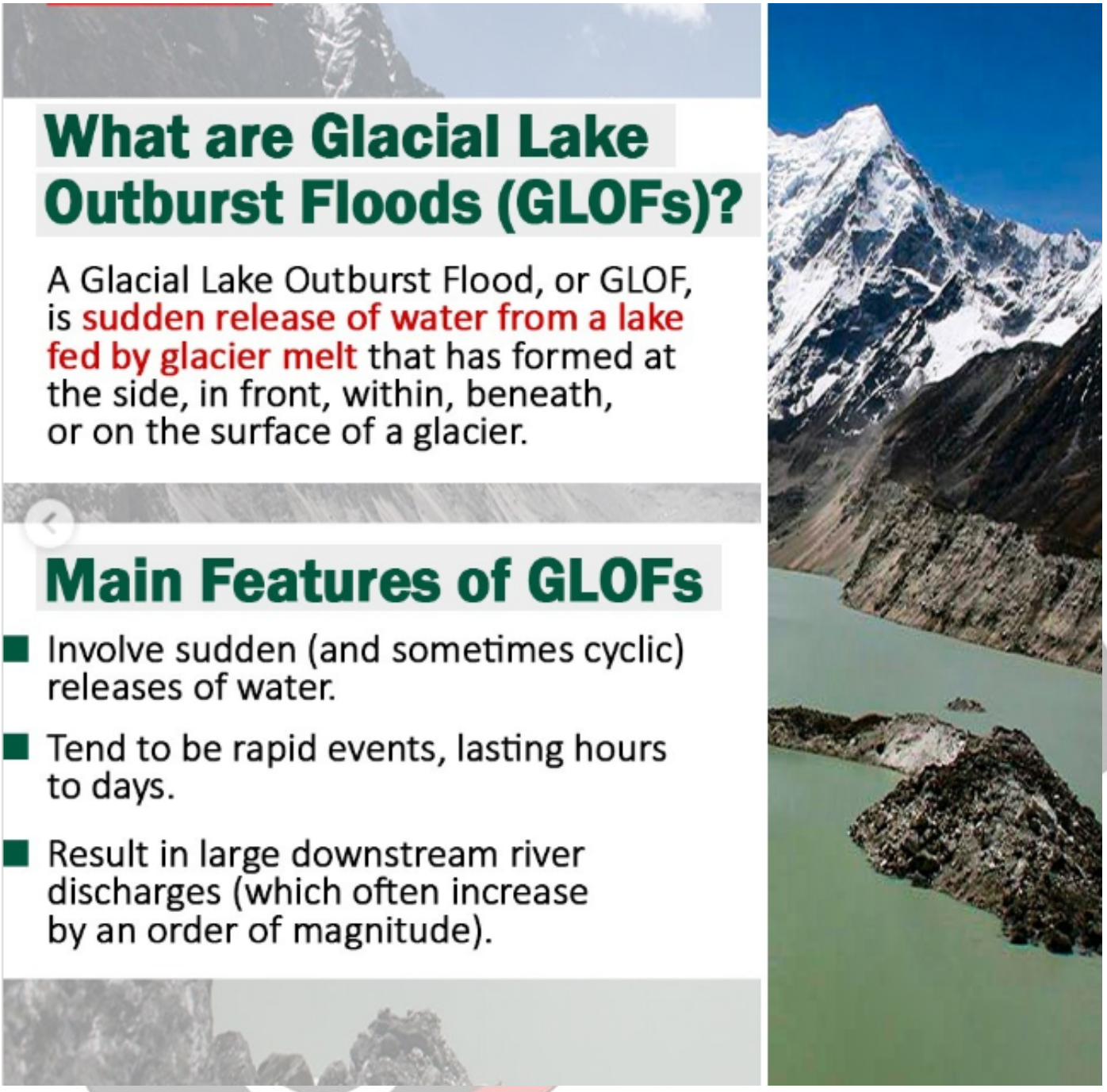
Source: TH

Why in News?

Frequent **Glacial Lake Outburst Flood (GLOF) incidents in Nepal** have heightened concerns in the **Indian Himalayan Region (IHR)**, home to **thousands of glacial lakes** vulnerable to **climate-induced disasters**.

What is a Glacial Lake Outburst Flood (GLOF)?

- **About: GLOF** is a **flood** resulting from the **sudden and rapid release of water** from a **glacial lake,** often caused by the **failure of a moraine (loose rock and debris) dam or ice dam.**



- **Causes:**
  - **Glacial Retreat due to Climate Change:** Accelerated melting in the **Indian Himalayan Region (IHR)** has led to the formation of over **7,500 glacial lakes**, many above **4,500 m**, often dammed by unstable moraines. Eg: 2013 **Uttarakhand floods** triggered by glacial melt and heavy rainfall.
  - **Cloudbursts & Extreme Rainfall:** Sudden intense rainfall raises lake water levels, stressing weak moraine dams. **Eg**: **Kedarnath GLOF (2013)**, **North Sikkim GLOF (June 2023)**.
  - **Avalanches & Landslides:** Ice/rockfall into lakes causes displacement waves, breaching dams. Eg: **Chamoli (2021)**, **South Lhonak lake (2023)**.
  - **Seismic Activity:** The Himalayas fall under **Seismic Zones IV and V**, making the region highly prone to earthquakes. Eg: **2015 Nepal Earthquake** altered lake stability, raising GLOF threats.
  - **Internal Seepage & Weak Moraines:** Piping erosion weakens moraine dams, causing sudden breaches. Eg: **1985 Dig Tsho GLOF**, Nepal.
  - **Unregulated Infrastructure Development**: Construction of **hydropower projects,**

roads, and settlements in glacial and riverine zones destabilizes fragile ecosystems.
    - Eg: The **Teesta-III Dam**, a major hydropower project, was **destroyed during the 2023 Sikkim GLOF**.

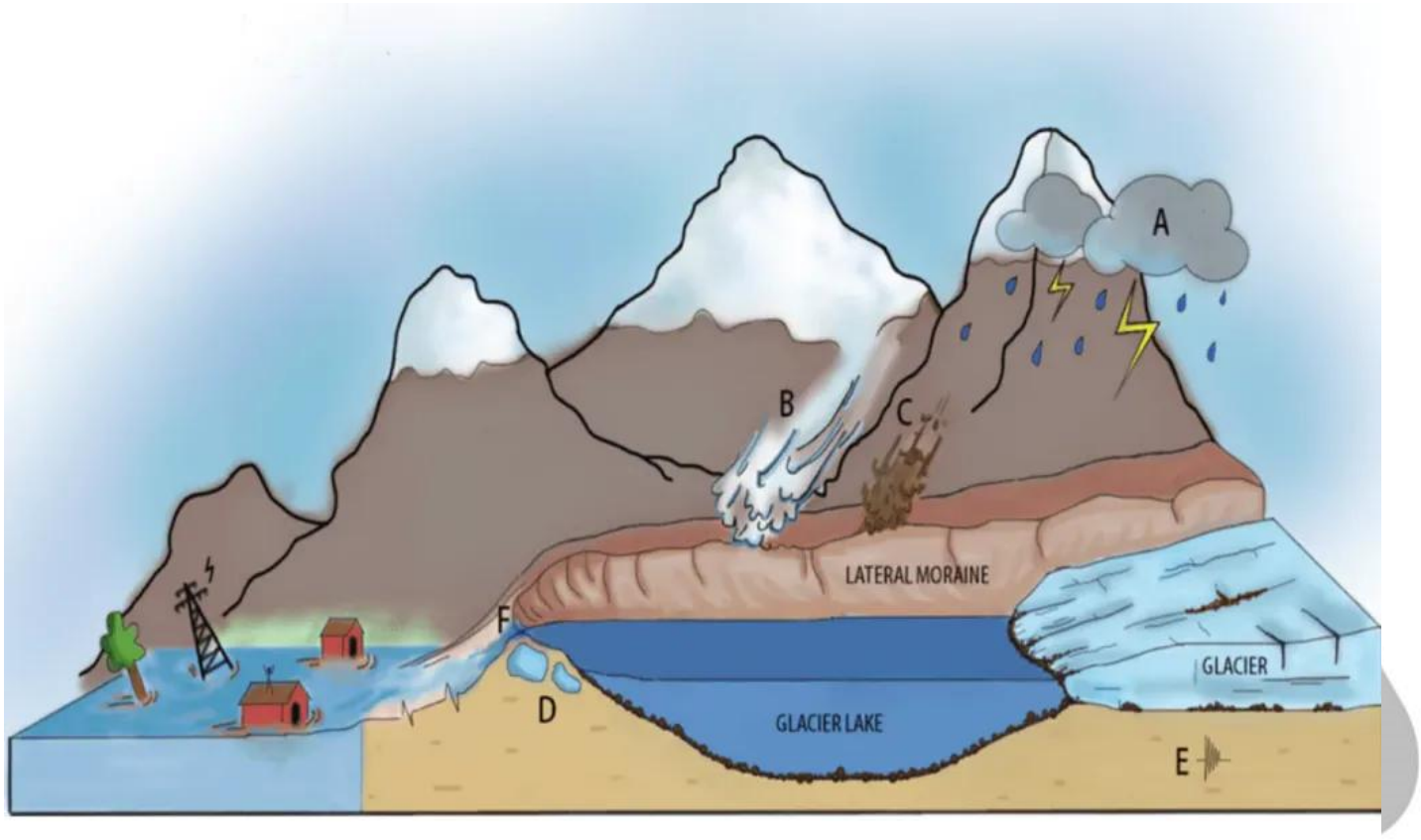


Figure: Illustrative graphic showing various reasons for GLOF occurrence
(A) Cloudburst (B) Snow avalanche (C) Landslide (D) Melting of ice in moraine
(E) Earthquake (F) Overflow

Types of Glacial Lakes in Himalayas

- **Supraglacial Lakes**: Form on the **surface of glaciers** due to **meltwater accumulation**; highly vulnerable during **summer melting**.
- **Moraine-dammed Lakes**: Located near the **glacier snout**, held by **loose debris or ice-core moraines**; **structurally weak** and prone to **sudden failure under external stressors**.

What is India's Vulnerability to GLOFs (Glacial Lake Outburst Floods)?

- **Geographic Extent & Vulnerability:** The **Indian Himalayan Region (IHR) spans 11 major river basins** and contains over **28,000 glacial lakes**, of which **7,500 are within India**, mostly located **above 4,500 metres**.
    - These high-altitude lakes are remote and difficult to access, limiting **year-round monitoring** and **physical surveys**.
    - **ISRO's satellite data (1984–2023)** shows that out of **2,431 glacial lakes** (>10 ha) identified in **2016–17**, **676 have significantly expanded**, with **601 more than doubling**, highlighting growing **GLOF vulnerability** in the region.
- **Past GLOF Events:** The **2023 South Lhonak GLOF (Sikkim)** destroyed the **Rs 16,000 crore Chungthang hydropower project**, increased **silting in the Teesta river**, and reduced **riverbed capacity**, raising downstream **flood risk**.

    - The **2013 Chorabari GLOF (Uttarakhand)** triggered a **cascading disaster** involving **cloudbursts**, **landslides**, and **massive fatalities** during the Kedarnath tragedy.
- **Climatic Triggers**: GLOF risk is rising due to **climate change**, **fragile topography,** and l**ack of robust early warning systems**. About **two-third (66%) of GLOFs** are caused by **ice avalanches or landslides**, while others result from **meltwater pressure** on weak moraine dams or **seismic activity**.
    - The record-breaking heat of **2023 and 2024** and the emergence of **localized extreme heat pockets** have further intensified glacial melt and **GLOF susceptibility**.
- **Monitoring Limitations:** India lacks **automated weather and water monitoring systems** in glacial regions due to **high costs and challenging terrain**.
    - Current monitoring relies heavily on **remote sensing**, which tracks **lake surface expansion** but provides **limited predictive capability** and is largely **post-facto**.
- **Risks to Downstream Assets**: GLOFs can cause **widespread destruction** of **homes**, **critical infrastructure**, and **hydropower projects**.
    - They lead to **loss of biodiversity** and increase **sediment load** in river systems, which reduces **riverbed capacity** and raises the risk of **secondary flooding** in downstream regions.

What Measures Have BeenTaken by India to Mitigate GLOF Risk?

- **National GLOF Mitigation Programme:** **NDMA (National Disaster Management Authority)** launched a **USD 20 million programme** targeting **195 high-risk glacial lakes** (initially 56), classified into **4 risk categories**.
    - This shift from **post-disaster relief to pre-disaster risk reduction** is coordinated through the **Committee on Disaster Risk Reduction (CoDRR)**, with further **scale-up planned under the 16th Finance Commission (2027–31)**.
- **Scientific & Technological Interventions:** Since 2024, **multi-institutional expeditions** in **6 Himalayan States** have used advanced tools like:
    - **Bathymetry** to measure water volume.
    - **Electrical Resistivity Tomography (ERT)** to detect **ice-cores** beneath **moraine dams**.
    - **UAVs** and **slope stability surveys** for terrain mapping.
    - **Indigenous technology** such as **SAR interferometry** is being promoted to detect **micro-slope shifts**, while **Automated Weather and Water Stations (AWWS)** in **Sikkim** relay **real-time data every 10 minutes**, including **daily lake imagery**.
- **Security Forces & Local Participation:** In remote **high-altitude areas** lacking automated systems, **ITBP personnel** are trained for **manual early warning**.
    - Expeditions also involve **local communities**, ensuring **cultural sensitivity** at **sacred sites** and building **trust** through **inclusive planning** and **awareness efforts**.

NDMA’s 5-Fold Strategy

- **Hazard Assessment** of all vulnerable glacial lakes.
- Install **Automated Weather & Water Stations (AWWS)** for real-time monitoring.
- **Early Warning Systems (EWS)** in downstream areas.
- **Risk Mitigation** via controlled lake drawdown and structural measures.
- **Community Engagement** through awareness, preparedness, and trust-building.

Way Forward

- **Advanced Monitoring & Early Warning:** Implement **Automated Weather Warning Systems (AWWS)**, **remote sensing**, and **Synthetic-Aperture Radar (SAR)** for real-time glacial lake surveillance. Introduce **automated alerts**, **community-based warning systems**, and **controlled drainage via spillways** to proactively reduce lake volumes and avert GLOFs.

- **Indigenous Solutions & Resilient Infrastructure:** Encourage **startups**, **academic R&D**, and **indigenous cryosphere technologies**; strengthen **moraine dams**, enforce **uniform construction codes**, develop **flood barriers**, and ensure **hydropower projects** align with GLOF safety standards.
- **Institutional, Transboundary & Community Action:** Train **SDRFs** for high-altitude response, foster **data sharing** and **joint risk mitigation** with **Nepal and China**, mandate **GLOF impact assessments** for all Himalayan projects, empower **panchayats**, conduct **mock drills**, and embed **resilience in local development planning**.

Conclusion

India faces a **high and growing risk** from GLOF events due to climatic, geological, and infrastructural vulnerabilities. The combination of inaccessible terrain, lack of early warning systems, and increasing glacial melt calls for urgent **risk mapping, surveillance**, and **community-integrated mitigation strategies** in the IHR.

Drishti Mains Question:

Glacial Lake Outburst Floods (GLOFs) are rising threats in the Himalayas. Discuss their key drivers, impacts, and India's mitigation strategies.

UPSC Civil Services Examination, Previous Year Question (PYQ)

Prelims:

Q. Siachen Glacier is situated to the (2020)

(a) East of Aksai Chin

(b) East of Leh

(c) North of Gilgit

(d) North of Nubra Valley

Ans: (d)

Q. Consider the following statements: (2010)

1. On the planet Earth, the fresh water available for use amounts to about less than 1% of the total water found.
2. Of the total fresh water found on the planet Earth 95% is bound up in polar ice caps and glaciers.

Which of the statements given above is/are correct?

(a) 1 only

(b) 2 only

(c) Both 1 and 2

(d) Neither 1 nor 2

Ans: (a)

Mains:

Q. With reference to National Disaster Management Authority (NDMA) guidelines, discuss the measures to be adopted to mitigate the impact of the recent incidents of cloudburst in many places of Uttarakhand. (2016)