



GLOF GUIDELINES

Glacial Lake Outburst Flood

Risk Management through Early Warning & Interventions

2026



MONITOR



ALERT



PREPARE



RESPOND



BUILD
RESILIENCE

National Disaster Management Authority (NDMA)

Government of Pakistan

Working Together
for a Safer Pakistan

1. Situation Analysis

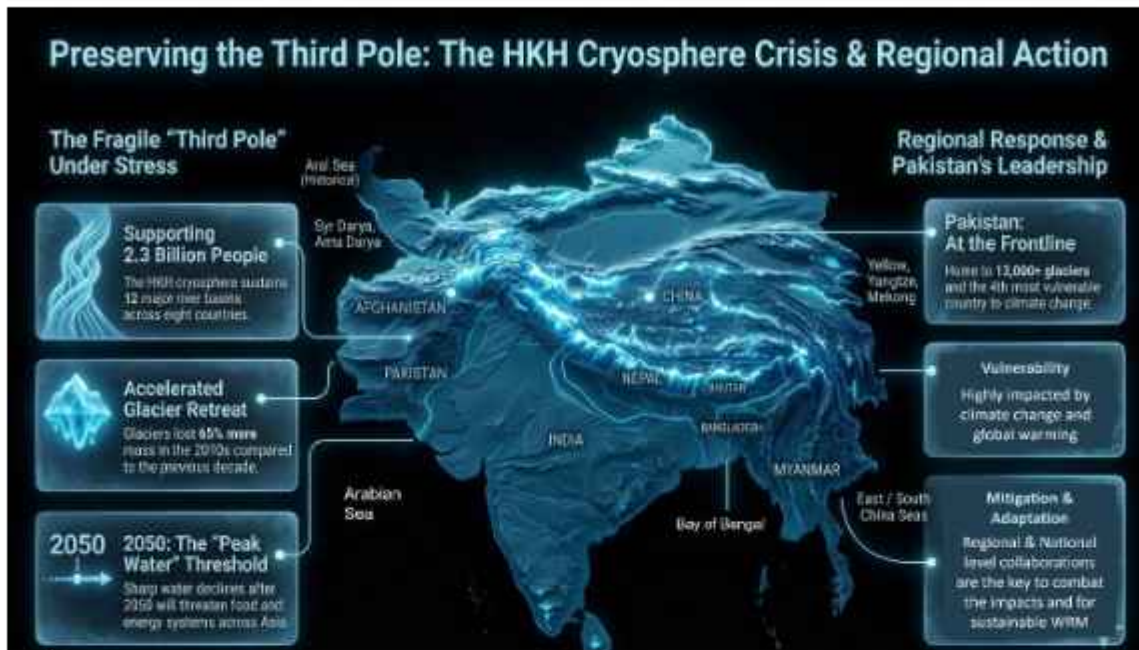
Pakistan faces a significant and increasing risk of Glacial Lake Outburst Floods (GLOFs) in 2026 due to continued climate change–driven glacier melt. The Himalayan, Karakoram, and Hindukush (HKH) ranges, which host thousands of glaciers, contain a growing number of glacial lakes formed by accelerated melting. Many of these lakes are dammed by unstable moraines, making them highly vulnerable to sudden failure and the release of large volumes of water downstream.

In 2026, the GLOF risk is further intensified by increasing climate variability, including erratic precipitation patterns, extreme rainfall events, and sustained temperature rise across high-mountain regions. These factors are accelerating glacier destabilization, expanding glacial lake volumes, and increasing hydro-geomorphic instability. At the same time, infrastructure development in high-altitude valleys continues to modify natural drainage systems, amplifying exposure and downstream impacts. Pakistan contains one of the largest concentrations of glaciers outside the polar regions, with approximately ~13,000 glaciers in the HKH region, all of which are increasingly sensitive to rapid cryospheric change.

The vulnerability is compounded by socio-economic fragility in downstream mountain communities. Many settlements are located directly within flood and debris-flow pathways, with limited access to early warning systems, evacuation infrastructure, and disaster-resilient construction. A GLOF event could result in severe consequences including loss of life, infrastructure damage (roads, bridges, hydropower), disruption of agriculture and livelihoods, and long-term ecological degradation in affected valleys.

Reducing GLOF risk in 2026 requires strengthened end-to-end early warning systems, continuous monitoring of glacial lakes using remote sensing and in-situ networks, and basin-scale risk assessments integrated into planning processes. Priority actions include improved disaster preparedness at community level, climate-resilient infrastructure development, regulated land-use planning in hazard-prone zones, and enhanced national and international cooperation for data sharing and technical support. A

coordinated approach among policymakers, NDMA, provincial authorities, and scientific institutions is essential to build resilience in Pakistan's vulnerable mountain regions.



2. Methodology.

a. **GLOF Investigation.** Glaciers and glacial lakes are generally located in remote areas mainly in the high mountains accessible mostly through tough and difficult terrain. Creating inventories and monitoring of the glaciers, glacial lakes, and extent of GLOF impact downstream can be done quickly and correctly using satellite images and aerial photographs. Visual and digital image analysis techniques integrated with techniques of GIS are very useful for the study of glaciers, glacial lakes, and GLOFs. Satellite Remote Sensing data and Geographic Information System techniques offer strong advantages for rapid and qualitative hazard assessments of glacier lakes.

(1) **Features of a Glacial Lake** A glacial lake is a water body formed in association with glaciers, either through glacial erosion or as a result of melting ice. These lakes exhibit several key characteristics that are essential for their identification, monitoring, and hazard assessment:

(a) **Geographic Location.** The position of a glacial lake is defined using coordinates, typically representing its centroid, derived through digitization of satellite imagery and GIS-

based mapping.

- (b) **Elevation**. Glacial lakes are generally located in high-altitude mountainous regions. Their elevation varies depending on glacier dynamics, regional climate, and surrounding topography, often occurring above 4,000 meters in the HKH region.
- (c) **Slope**. The slope around a glacial lake is influenced by local terrain and glacier morphology, ranging from flat surfaces to very steep gradients (0° – 90°), which can affect lake stability and outburst potential.
- (d) **Aspect**. Aspect refers to the directional orientation of the lake or its drainage pathway, categorized into the eight principal compass directions (N, NE, E, SE, S, SW, W, NW). For closed lakes, orientation is defined along the major axis.
- (e) **Area**. The surface area of a glacial lake is calculated using satellite imagery and geospatial datasets, forming a critical parameter for assessing lake growth and hazard potential.
- (f) **Depth**. Lake depth is estimated along cross-sectional profiles. Average and maximum depths are derived using empirical relationships and available field or modeled data.
- (g) **Volume**. The volume of a glacial lake is estimated using empirical formulas that relate surface area and depth, typically expressed in cubic meters (m^3), and is a key indicator for potential GLOF magnitude.
- (h) **Activity**. According to their stability, the glacial lakes are divided into three types: Stable, Potentially Dangerous, and Outburst (when there have been previous bursts).
- (i) **Type of Water Drainage**. Glacial lakes are divided into drained lakes and closed lakes according to the drainage condition.

3. Glacial Lakes Inventory

(a) **Classification of Lakes** Glacial lakes in the Hindu Kush–Karakoram–Himalaya (HKH) region are classified into the following major types based on their geomorphological origin, glacier association, and damming mechanism:

- | | |
|--|---|
| (1) Erosion Lakes | (10) Ice-Marginal Lakes |
| (2) Depositional Lakes | (11) Cirque Lakes |
| (3) Supraglacial Lakes | (12) Valley Lakes |
| (4) Moraine-Dammed Lakes | (13) Bedrock-Dammed Lakes |
| (5) Lateral Moraine-Dammed Lakes | (14) Englacial Lakes |
| (6) End Moraine-Dammed Lakes | (15) Subglacial Lakes |
| (7) Ice-Dammed Lakes | (16) Detached / Unconnected Glacial Lakes |
| (8) Blocked Lakes (Landslide/Ice Blockage Lakes) | (17) Thermokarst / Kettle Lakes |
| (9) Proglacial Lakes | |

Figure: Types of Glacial Lakes



- b. **Glacial Lakes in Upper Indus Basin.** Identification and assessment of glacial lakes is important not only as resource management point of view but also for monitoring of GLOF hazards in the downstream region. For the inventory of glacial lakes, the lakes associated with perennial snow and ice, originate from glaciers, and in some cases the isolated lakes found in the mountains and valleys far away from the glaciers are considered.
- c. **NEOC's Snow Cover Projections April-September 2026.** Below are the snow projections developed by NEOC's Tech EW team for the months of April to August 2026.

Figure: Monthly Snow Cover – 2026



Table: Projected Seasonal Snow Cover Change (%) w.r.t. Temperature (°C)

Month	Projected Temp Range (2026)	Projected Snow Cover Change (%)	Key Interpretation
May	9.5 → 12	12–13%	Earlier snowmelt onset; increased runoff
Jun	12 → 16.5	13–14%	Accelerated melt transition phase
Jul	12 → 18.5	14–15%	Peak snow depletion begins earlier
Jul	18.5 → 21.5	15–16%	Maximum melt intensity; glacier contribution rises

Aug	21 → 22.5	15–17%	Sustained high melt; risk of GLOFs increases
Sep	21.5 → 20	6–7%	Reduced melt but delayed cooling keeps runoff elevated

4. **Mapping Vulnerable GLOF Sites in Pakistan.** In Pakistan, the National Disaster Management Authority, through the National Emergency Operations Centre (NEOC), maintains continuous monitoring of glacial lakes using satellite remote sensing, in-situ observations, and coordination with provincial and regional line departments. As of 2026, Pakistan's northern regions—particularly Gilgit-Baltistan and upper Khyber Pakhtunkhwa host over 4,000–4,500 glacial lakes, of which around 50 sites have been identified as vulnerable, including 12–14 highly critical locations requiring priority monitoring.

Figure: Glaciers and Glacial Lakes Profile of Pakistan



- a. **Glacial Lakes by Various Types.** Most of the lakes in HKH region belong to erosion type followed by End-moraine dammed type.

Table: Summary of glacial lakes by various types in UIB - 2026

Type of Lake	Estimated Number	% Share	Estimated Area (km ²)	Hydro-Met Sensitivity	GLOF Risk Level	Key Drivers (2026)
End Moraine-Dammed	~1,150–1,300	~28–30%	~70–80	Very High	Critical	Rapid snowmelt, temperature rise, rainfall, moraine instability
Valley Lakes	~300–380	~7–9%	~18–22	High	High Impact	Sudden inflow pulses, large storage volume
Erosion Lakes	~2,000–2,200	~50–52%	~110–125	Low–Moderate	Moderate	Gradual melt, basin-controlled hydrology
Supraglacial Lakes	~450–520	~11–12%	~4–6	Increasing	Emerging	Glacier surface melt, debris cover, coalescence
Blocked Lakes	~70–100	~2–3%	~4–7	Episodic (High when triggered)	Critical (Event-based)	Landslides, ice blockage, extreme rainfall
Cirque Lakes	~130–180	~3–5%	~7–10	Low	Low	Limited inflow variability
Lateral Moraine-Dammed	~15–30	<1%	~0.3–0.8	Very Low	Low	Small size, limited storage

- b. **GLOF Triggers.** A glacial lake’s susceptibility to a GLOF event is evaluated considering the set of parameters outlined in the table below.

Table: GLOF Triggers with Criteria Values

Ser	Parameters	Selection Criteria	Source
1	Area of the Lake	>0.1 Km ²	Satellite Imagery
2	Volume of Lake	10×10 ⁶ - 100×10 ⁶ m ³ High	Empirical Formula
3	Type of Lake	Moraine dammed lake High Ice dammed lake Medium Bedrock dammed lake Low	Google Earth
4	Moraine width o height ratio	<1 High	Google Earth/SRTM
5	Elevation	> 4000 meters A.S.L.	SRTM
6	Aspect	NS, SE	SRTM
7	Drainage	Closed Open	Google Earth/ Satellite Imagery
8	Distance from Glacier	<80 m High 80-600 m Medium	RGI v.6/Satellite Imagery
9	Slope of Lake	>40°	SRTM
10	Spatio-Temporal Change	LULC	Satellite Imagery
11	Distance to the Impact Area	>10m	Satellite Imagery
12	Distance from Fault Line		
13	Lake Growth per Decade	>100% High 50-100% Medium	Satellite Imagery
14	Extreme Met. Events	Frequent: High Sporadic: Medium	AIRS/TRMM / CHIRPS

Table: Hydro-met Parameters of GLOF Triggers with Criteria Values

Ser	Trigger	Description (HKH Context)	Mechanism	Indicative Threshold / Signal
1	Air Temperature Rise	Above-normal warming at high altitudes accelerates glacier melt	Increased meltwater inflow → lake expansion	+2°C to +4°C anomaly (>3000 m)

2	Rapid Glacier Melt	Enhanced ablation during summer months	Increased discharge into glacial lakes → hydrostatic pressure	Peak melt (Jun–Aug)
3	Intense Rainfall / Cloudbursts	Localized extreme precipitation events common in Chitral/GB	Sudden inflow + moraine erosion → overtopping	>50–100 mm/day (or short-duration bursts)
4	Prolonged Rainfall	Multi-day rainfall events saturating moraine dams	Seepage, piping, and structural weakening of dam	3–5 consecutive rainy days
5	Rain-on-Snow / Late Snowfall Events	Rainfall over existing snowpack at mid-high elevations	Rapid snowmelt + runoff surge into lakes	Spring overlap (Mar–Jun)
6	Early Snowmelt Shift	Snowmelt occurring earlier due to warming	Sudden early-season runoff peaks	Feb–Apr shift
7	Monsoon Intensification / Intrusion	Increased monsoon penetration into Karakoram	Sustained inflow into lakes → overtopping risk	Above-normal monsoon (Jul–Aug)
8	Extreme Weather Events (Compound)	Combined temperature spikes + rainfall events	Multi-hazard cascade (flood + landslide + GLOF)	Concurrent extremes
9	Permafrost Thaw (Hydro-linked)	Rising temperatures degrade frozen ground	Moraine/slope instability → lake disturbance	Long-term warming trend
10	Snowpack Variability	Low snow accumulation followed by rapid melt	Reduced buffering → flash runoff into lakes	Below-normal snow + rapid warming
11	Lake Level Rise Rate	Rapid increase in lake water level	Imminent overtopping or breach risk	Sudden rise (cm–m/day)
12	Glacier Surge Interaction	Surge-type glaciers blocking drainage	Formation of temporary lakes → sudden release	Episodic (multi-year cycles)

- c. **Most Vulnerable GLOF Sites**. The most vulnerable GLOF/Flash Floods/ Debris Flow Risk Zones with most vulnerable sites of Pakistan are identified as shared in the figures below. Notable high-risk glaciers and associated lake systems include: Khurdopin, Ishkoman, Badswat, Shisper, Hinarchu, Hundur, Ghulkin, Darkut, Reshun, Brep, Booni, Pindoru Chat, Chatiboi, Lasht, Sardar Gol, Thalu 1 & 2, Arkari, Owir, etc.

These sites are characterized by rapid glacial melt, expanding moraine-dammed lakes, steep valley gradients, and exposure to extreme weather events, all of which elevate the likelihood of outburst floods. Recent cryosphere assessments indicate that reduced snow persistence and rising temperatures in 2026 are contributing to earlier and more rapid meltwater inflows, increasing pressure on unstable lake boundaries.

Figure: Spatial Distribution of GLOF Sites of Pakistan

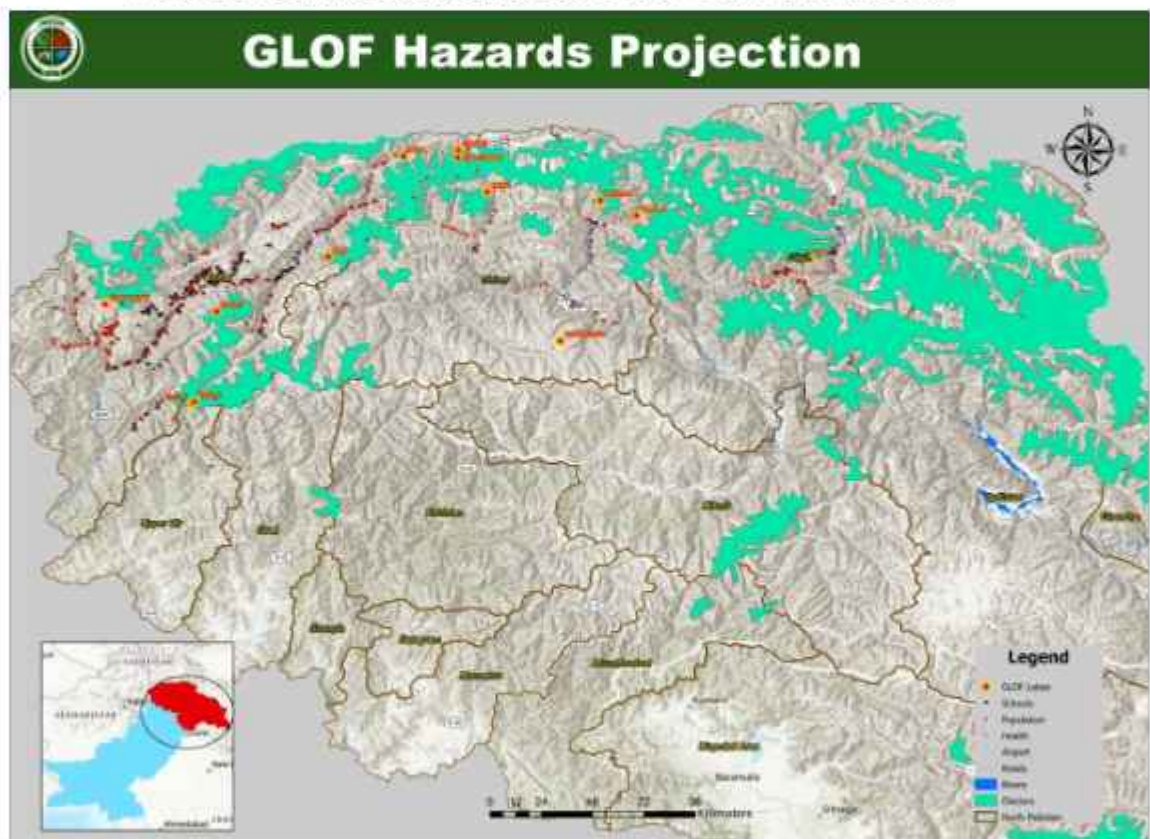


Figure: GLOF/Flash Floods Risk Zones -



Figure: GLOF Risk Zones - Ghizer

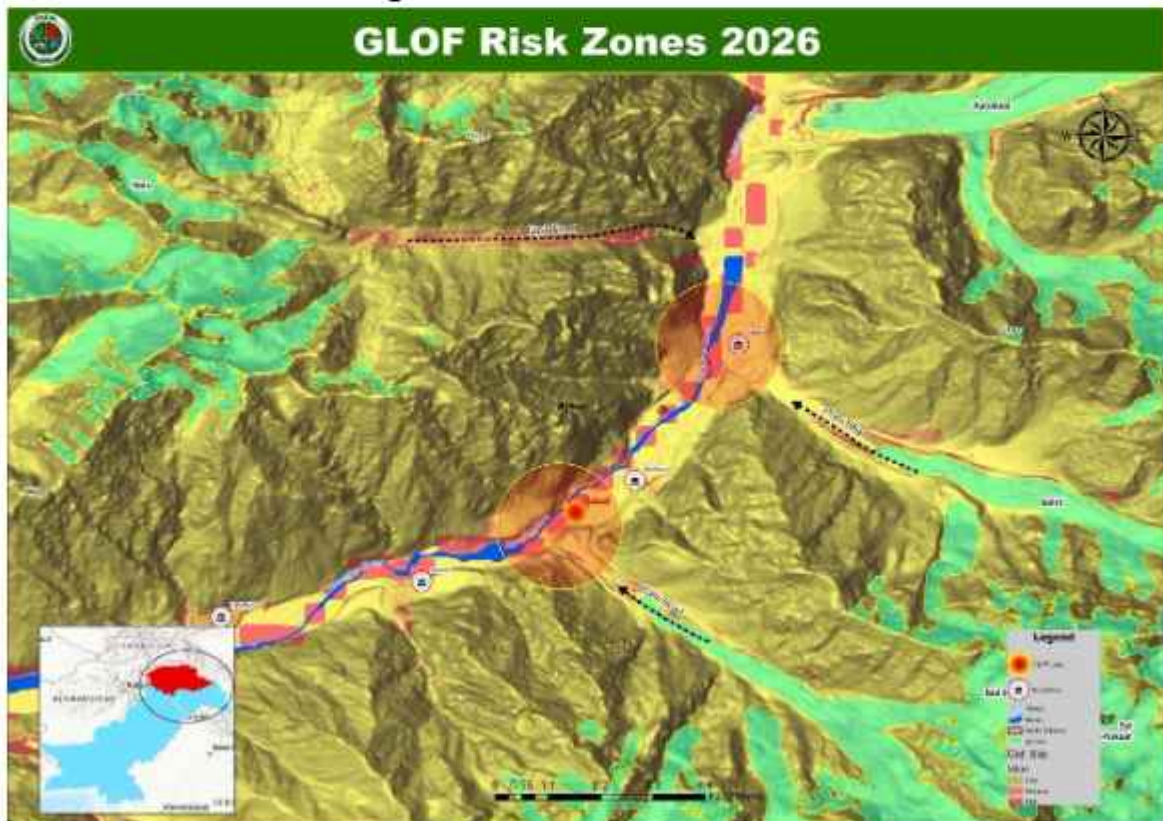


Figure: GLOF/Flash Floods Risk Zones – Chitral



Figure: GLOF/Flash Floods Risk Zones - Gulmit



Figure: GLOF/Flash Floods Risk Zones - Darkut



Figure: GLOF/Flash Floods Risk Zones - Chapursan



Figure: Ishkoman Glacial Lake Impact Map

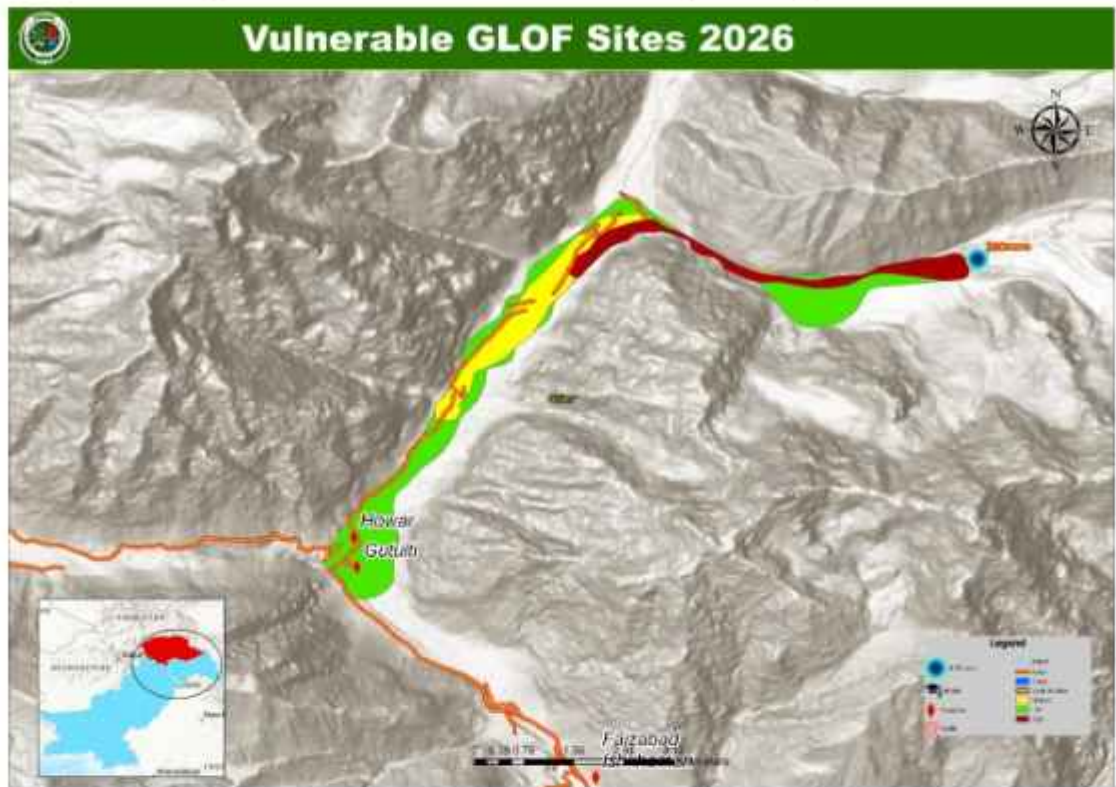


Figure: Lusht Glacial Lake Impact Map



Figure: Ulter Glacial Lake Impact Map

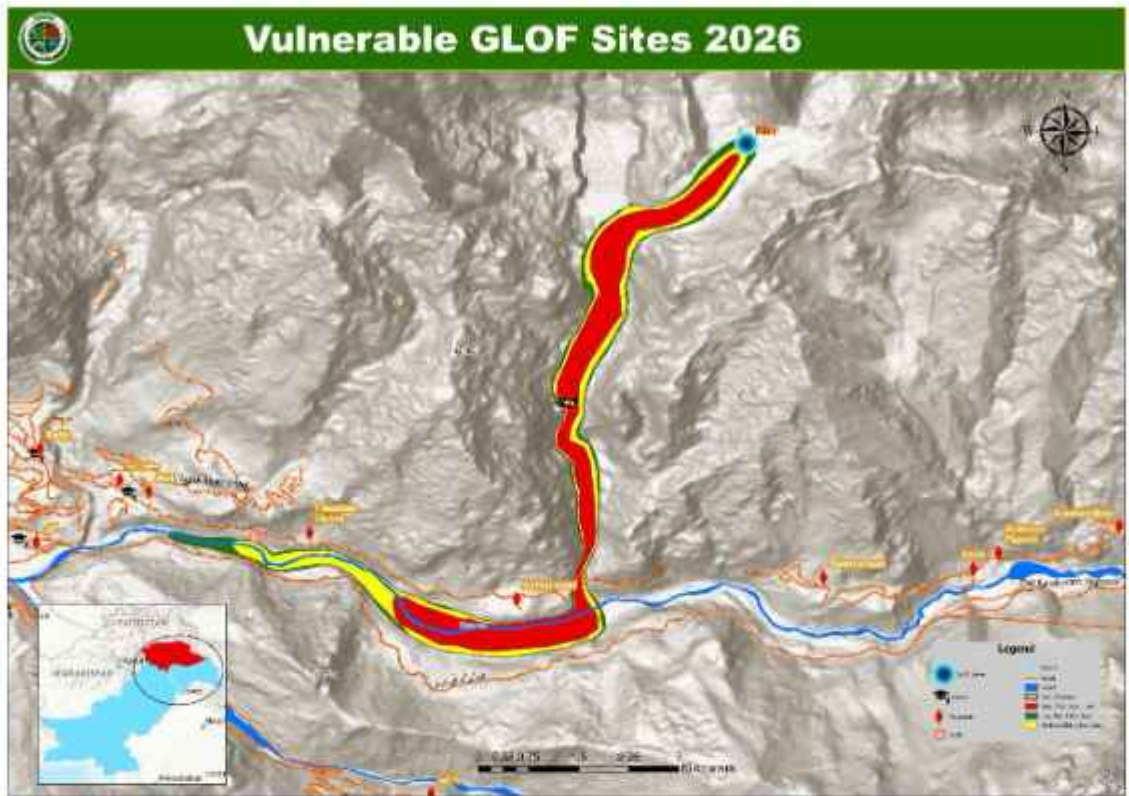
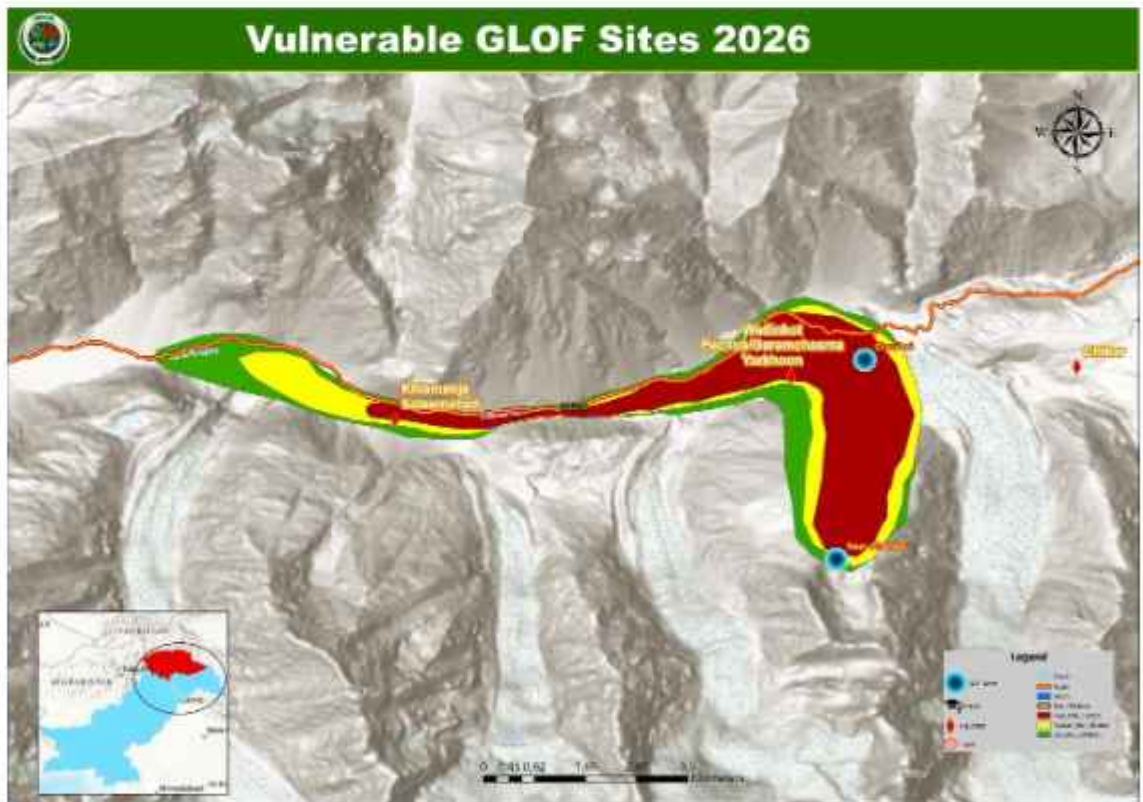
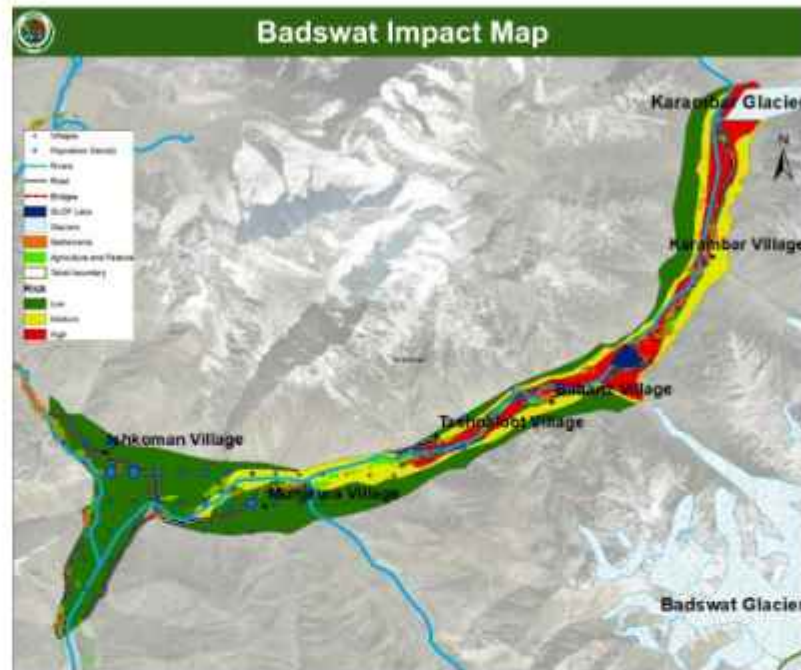


Figure: Chatbai Glacial Lake Impact Map



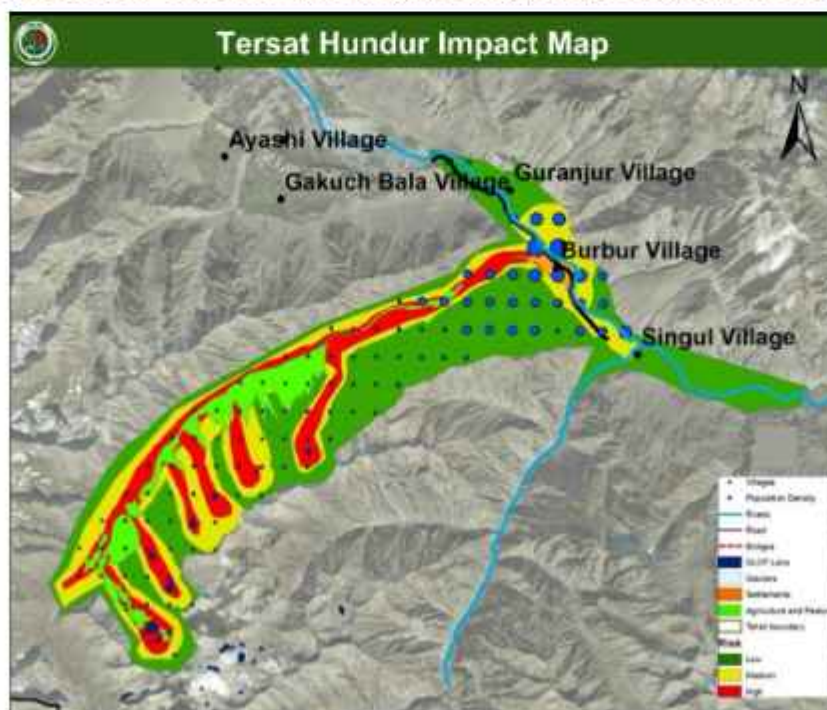
- (1) **Badswat Glacial Lake.** Badswat glacial lake in Ghizer, GB is highly vulnerable to GLOF.

Figure: Badswat Glacial Lake Impact Map



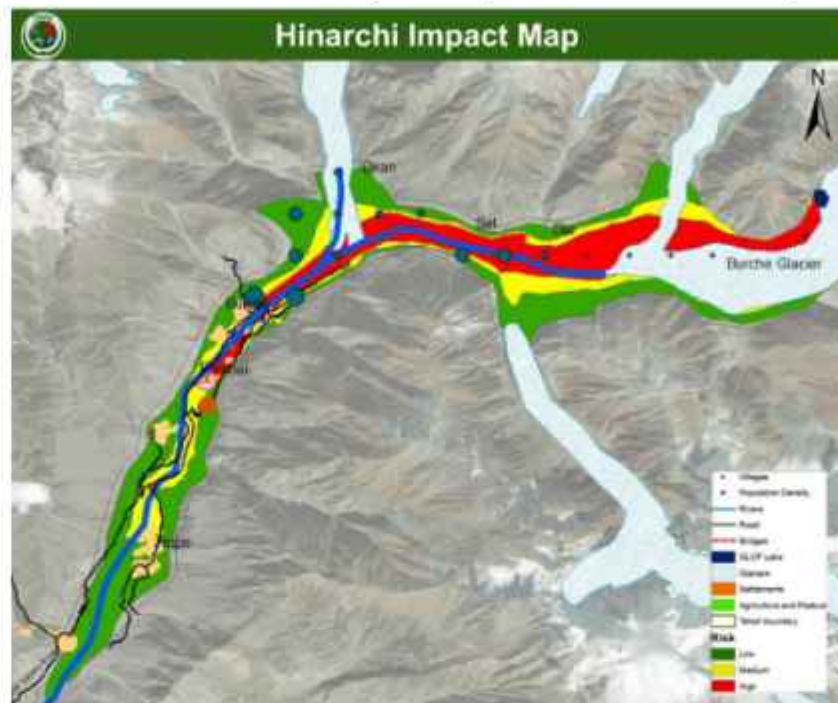
- (2) **Tersat Hundur Glacial Lake.** Tersat Hundur glacial lake in Ghizer, GB is highly vulnerable to GLOF.

Figure: Tersat Hundur Glacial Lake Impact Map with Estimated Exposure



- (3) **Hinarchi Glacial Lake**. Hinarchi glacial lake in Gilgit, GB is highly vulnerable to GLOF.

Figure: Hinarchi Glacial Lake Impact Map with Estimated Exposure



- (4) **Reshun Glacial Lake**. Reshun glacial lake in Chitral is highly vulnerable to GLOF.

Figure: Reshun Glacial Lake Impact Map with Estimated Exposure

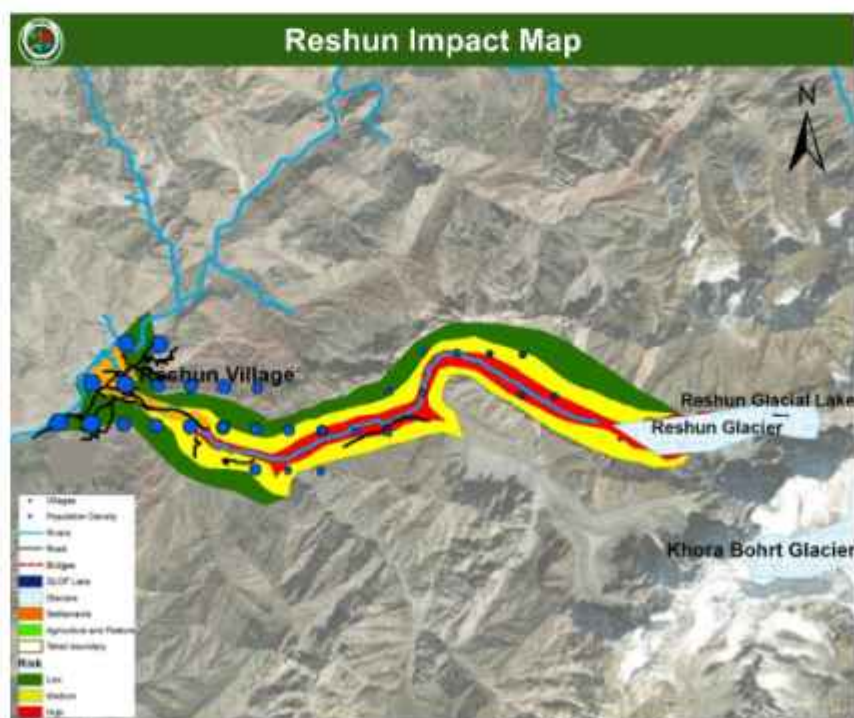


Figure: Volumetric Analysis of Vulnerable GLOF Lakes



5. National & Global Best Practices

a. Prevention Strategies

- (1) Reducing GLOF risks in Pakistan requires a combination of structural measures, scientific monitoring, ecosystem-based adaptation, and community preparedness. Small-scale engineering interventions such as controlled drainage systems, spillways, siphoning, mini/check dams, embankments, and gabion structures should be implemented to reduce downstream flood impacts and stabilize vulnerable glacial lakes.
- (2) **Installation of hydro-meteorological monitoring** systems including automatic weather stations, lake-level sensors, and early warning mechanisms is essential for real-time monitoring and timely dissemination of alerts through SMS, FM radios, sirens, and community networks. Hazard modelling and continuous satellite-based monitoring should support impact-based forecasting and preparedness planning.

- (3) Nature-based solutions** including afforestation, agroforestry, slope stabilization, watershed restoration, and plantation of native species such as willow and poplar should be promoted to reduce erosion and enhance ecological resilience. Sustainable practices including snow harvesting, artificial glaciers, and water-efficient farming techniques may help improve water security and reduce pressure on unstable glacial systems.
- (4) Community awareness**, mock drills, evacuation planning, and establishment of Village Disaster Management Committees (VDMCs) should be strengthened in vulnerable valleys. Land-use regulations and hazard zonation should restrict construction, cultivation, and infrastructure development in flood-prone areas and high-risk glacial valleys.
- (5) Integration of indigenous knowledge**, scientific research, and coordinated institutional efforts among relevant national and provincial stakeholders remains critical for developing a proactive and resilient GLOF risk management framework in Pakistan.

Table: Global and Regional Best Practices Relevant to Pakistan

Country	Best Practice	Relevance for Pakistan
Nepal	Controlled lake lowering at Imja Lake	Moraine lake risk reduction
Bhutan	Automated GLOF warning systems	Remote mountain EWS
Switzerland	Glacier monitoring & hazard zoning	Alpine risk governance
Peru	Engineering spillways & lake drainage	Structural mitigation
Iceland	Real-time glacier flood forecasting	Ice-dammed Lake monitoring
China	Integrated remote sensing surveillance	HKH glacier inventory development

- b. Guidelines for Vulnerable Communities.** Natural hazards in mountainous regions such as flash floods, landslides, avalanches, and GLOFs can occur suddenly and with severe impacts. Preparedness, timely

response, and community coordination are essential to minimize loss of life and property.

- (1) Stay informed through official alerts (NDMA/PMD/PDMAs) and maintain a clear family emergency plan, including roles, responsibilities, and a designated meeting point.
- (2) Identify local hazard zones, safe evacuation routes, and nearest shelters in advance; participate in community drills and awareness activities.
- (3) Act immediately on early warnings and evacuation orders without delay; prioritize personal safety over belongings.
- (4) Remain calm during emergencies and support vulnerable individuals, including children, elderly persons, and persons with disabilities.
- (5) Keep copies of essential documents in waterproof storage and ensure emergency contact lists are updated and accessible.
- (6) Store emergency supplies (safe drinking water, non-perishable food, medicines, and basic first aid items) at secure and preferably elevated locations.
- (7) Maintain livestock evacuation plans separately, ensuring animals are moved to safe zones without compromising human shelter capacity.
- (8) Rely only on verified information from official sources and avoid spreading rumors or unconfirmed updates on social media.
- (9) Follow all instructions issued by local authorities and emergency responders without hesitation.
- (10) Before evacuation, safely switch off electricity, gas, and water supply; move valuables and important items to safer or elevated areas if time permits.
- (11) Keep a minimum stock of 1 gallon (3–4 liters) of safe drinking water per person per day and ensure it is free from contamination.
- (12) Store sufficient non-perishable food items (grains, canned goods, powdered milk, etc.) to maintain balanced nutrition during disruptions.
- (13) Maintain a well-equipped emergency kit including bandages, antiseptics, splints, and at least one week supply of essential prescription medications.

- (14) Ensure emergency preparedness accounts for the specific needs of infants, elderly family members, and persons with special needs.
- (15) Secure your home when safe to do so and evacuate early—do not wait until conditions deteriorate.

c. **Gap Analysis: Glacial Hazards Early Warning, Preparedness, and Community Resilience.** Despite the continuous monitoring, analysis, and timely dissemination of advisories, alerts, and projections by the NEOC Technical Early Warning (TEW) Wing, several systemic and operational gaps persist in strengthening end-to-end disaster risk management in high mountain regions.

- (1) **Last-mile delivery gap in early warning dissemination**
In remote and high-risk valleys such as Reshun, Booni, Ishkoman, Hassanabad, Kharmang, Ghanche, and upper Chitral, despite timely issuance of alerts and advisories by NEOC TEW Wing, challenges remain in ensuring rapid, understandable, and actionable communication to the most vulnerable and marginalized communities.
- (2) **Weak enforcement of land-use planning and protective infrastructure.** There is a persistent gap in zoning regulation enforcement in hazard-prone areas. Settlements and infrastructure continue to expand in vulnerable corridors without adequate structural mitigation such as check dams, retention basins, slope stabilization, and engineered embankments.
- (3) **Limited adoption of proactive hazard mitigation interventions.** Although monitoring and risk identification are regularly undertaken, proactive measures such as controlled lake siphoning, engineered drainage, and pre-emptive glacial lake risk reduction strategies remain insufficiently institutionalized and operationalized at scale.
- (4) **Unregulated development in fragile cryospheric zones.** Increasing infrastructure development, road expansion, and vehicular movement in high-altitude and glacier-adjacent areas is intensifying environmental stress and increasing exposure to cascading hazards.

- (5) **Absence of a centralized, dynamic glacier and glacial lake database.** A comprehensive, real-time national database integrating glacier retreat, lake evolution, and hazard dynamics is still lacking, limiting advanced modeling, prioritization, and decision-support for risk reduction planning.
- (6) **Incomplete vulnerability assessments.** Current risk assessments often emphasize physical hazard exposure while underrepresenting socio-economic vulnerability dimensions such as poverty levels, livelihood dependence, housing resilience, and access to emergency services.
- (7) **Preparedness-action gap at community level.** While NEOC TEW Wing continuously issues alerts and situational projections, field observations indicate that many communities—though aware of hazards—lack practical knowledge of emergency response, evacuation protocols, and survival actions.

d. Recommendations for GLOF Risk Reduction and Climate Resilience

Stakeholder	Key Recommendations
General / National Priority	Strengthen basin-level multi-hazard risk assessment for GB, KP, and AJK. Improve community awareness and last-mile early warning dissemination in remote valleys. Develop centralized national glacier and glacial lake database for Pakistan. Enhance resilience through early warning systems, infrastructure, institutions, and risk financing.
Academic & Research Institutions	Conduct focused research on glacier retreat, GLOF dynamics, and HKH cryosphere changes. Integrate satellite, hydromet, and field data for improved forecasting and early warning. Support development of climate-resilient infrastructure design for mountainous terrain.
Government (Federal / Provincial / NDMA, PDMA, DDMAs)	Expand and strengthen NEOC-based early warning systems with real-time glacier monitoring. Integrate GLOF risk into land-use planning and infrastructure development policies. Allocate dedicated funding for monitoring, mitigation, and community resilience programs. Establish and operationalize Community-Based Disaster Risk Management Committees and Hazard Watch Groups.

Local Communities & LSOs	Improve disaster preparedness through awareness, training, and evacuation planning. Strengthen community-based monitoring and response mechanisms. Promote safe evacuation routes and household-level preparedness kits.
Media	Ensure timely dissemination of NDMA/PMD alerts and verified hazard information. Promote public awareness on GLOF risks and preparedness actions. Support community engagement through interactive communication platforms.
Health Sector	Strengthen emergency medical response in GB, KP, and AJK hazard zones. Ensure availability of trauma care, WASH services, and disease surveillance post-disaster.
Development & NGOs/INGOs	Support livelihood diversification in glacier-dependent communities. Integrate GLOF risk reduction into development and climate adaptation projects. Provide emergency response and post-disaster recovery support.