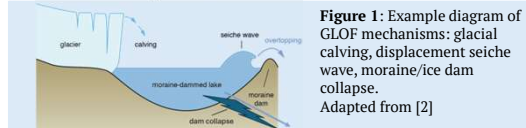


A Thawing Threat: The rise of glacier-related flash flooding as an expedition medicine hazard in the Nepali Himalayas

Dr. James Hayley MBBS MA(Oxon.)- Guy's and St. Thomas' NHS Foundation Trust

1: Introduction

Glacial lakes are formed when meltwater from a glacier is contained behind a natural dam- either a moraine (pile of rock and sediment deposited by a glacier) or glacier ice itself. These structures and the surrounding glacier can be unstable, resulting in sudden releases of water that present as flash floods concentrated in downstream valleys. This can occur via several mechanisms, including glacial-lake outburst floods (GLOFs) and ice-rock glacial collapses. Whilst timing of triggers of flooding events are unpredictable, glacial lakes share common geological risk factors that can predict local flooding hazard levels [1].



Global warming increases this risk via:
→ Increased glacial and permafrost melting.
→ Increased glacial lake volumes.
→ Destabilisation of ice in dam and overlying glacier.
As a result, incidence of glacier-related flooding may be increasing [3].

5.2 → 15.2 GLOFs/yr
1981-1990 vs. 2011-2020

2: Case Study - Langtang 2026

26 August 2026; Langtang National Park
Not a classical GLOF, but thought to be a glacial ice-rock collapse triggering a flash flood.
Best accepted version of events:
Glacial slope failure and landslide → temporary blockage of Lhende Khola river → rapid formation of glacial-type lake → debris dam breach → flash flooding with increasing severity as debris accumulates.

Facts and Figures:

- Water rise of up to 9m in 30 minutes
- Estimated casualties: ~1400 deaths, thousands remain missing- including several hundred of foreign tourists [4]
- Infrastructure damage: 37 motorable bridges and 68 suspension bridges destroyed [4].
- ~\$4.8bn damage [4]
- Injury patterns: Injuries caused by the ice-rock-debris flow and include trauma (blunt force and crush), drowning, burial and hypothermia- similar to classical flash flooding [5].

Casualty mitigation:

- Local early warning text alerts sent minutes before flood impact at populated areas are believed to have saved many lives.

3: Mapping High Risk Glacial Lakes Hazards On Himalayan Expedition Routes

We designed an interactive proof-of-concept beta map tool to identify at risk hiking routes in the Nepali Himalayas. This area was selected in response to the recent Langtang disaster (Box 2) and as the locale with highest density of potentially dangerous glacial lakes and concurrent high expedition tourism in the area.

Methods:

Route identification:

10 most popular Himalayan trekking routes identified from ©AllTrails database, comprising ~1000km of hiking area (with overlap). These were then plotted on native interactive mapping software (©Mapbox ©OpenStreetMap) using GPX files.

Risk stratification

High risk glacial lakes were identified in the UN Development Programme report [1] according to lake, glacier and dam geological criteria; graded risk I-III (n=47).

Coordinates were extracted and plotted on map (n=1 excluded as outside geographic range).

Routes stratified according to risk according to glacial lake risk criteria, proximity to high-risk lake and topography of floodpath:

- **LOW:** route encounters no risk lakes or only grade I risk lakes
- **MEDIUM:** route intersects with the floodpath of at ≥1 grade II risk lake
- **HIGH:** route intersects with floodpath of at ≥2 grade II risk lakes or any grade III lakes



Figure 2: Map of Potentially Dangerous Glacial Lakes (PDGLs) against popular Himalayan hiking routes- download from a proof-of-concept interactive navigation tool. Routes are coded by colour: PDGLs are labelled with a flag icon.

Route	Glacial Flooding Risk	Previous Flooding Events
Everest Base Camp	HIGH	Dig Tsho GLOF 1985; Tam Pokhari GLOF 1998; Thyanbo GLOF 2024
Everest Three Passes	HIGH	Dig Tsho GLOF 1985; Thyanbo GLOF 2024
Annapurna Circuit	MEDIUM	Nil previous- hazard modelled
Annapurna Base Camp	LOW	Nil previous- hazard modelled
Langtang Valley	HIGH	Earthquake with ice-rock collapse flood 2015; Lantang ice-rock collapse flood 2026
Manaslu Circuit	MEDIUM	Minor ice-rock collapse flood 2024
Makalu Base Camp	HIGH	Nil previous- hazard modelled
Rolwaling Valley	HIGH	Nil previous- hazard modelled
Kanchenjunga Base Camp	HIGH	>6 GLOFs recorded including Nangama GLOF 1980
Gokyo Lakes	HIGH	Nil previous- hazard modelled

4: Lessons for Expedition Medics

Pre-trip:

- Awareness of glacial-related flooding risk.
- Route selection: use of mapping features (such PoC tool developed here) to identify risks.
- Equipment: basic trauma adjuncts, hypothermia wraps, buoyancy aid, pocket mask/BVM, oximeter, low temperature thermometers.

En route:

- Identification of flood precursors (note: no predictable relationship with upstream rainfall as in classical flash floods).
- Communication: satellite phones to maintain comms if telecom infrastructure is destroyed, but use of mobiles with local SIM cards to receive local emergency hazard alerts.
- Identify primary evacuation routes to high ground while traversing valleys.
- Plan secondary evacuation routes that do not rely of vulnerable bridge infrastructure where possible.

Field triage priorities

Mass casualty triage adapted for destroyed infrastructure, low resource setting:

- Airway & drowning
- Rapid haemorrhage and crush-injury control
- Hypothermia prevention

5: Conclusions

The rapid and catastrophic nature of glacial-related flooding events makes these a significant hazard from an expedition medicine perspective.

Incidence of these events is increasing, and hence so too must awareness and preparedness.

At the expedition planning stage, navigation tools combining expedition routes with geological hazard data pertaining to glacial lakes could add value for route selection and evacuation planning.

6: References

1. Bajracharya, S.R., Maharjan, S.B., Shrestha, F., Sherpa, T.C., Wagle, N., Shrestha, A.B. (2020). *Inventory of glacial lakes and identification of potentially dangerous glacial lakes in the Koshi, Gandaki, and Karnali River Basins of Nepal, the Tibet Autonomous Region of China, and India*. Research Report. ICIMOD and UNDP.
2. Bendle, J. (2025) *Glacial Lake Outburst Floods (GLOFs)*. Report. Antarctic Glaciers. <https://www.antarcticglaciers.org/glaciers-and-climate/glacier-hazards/glacial-lake-outburst-floods/>
3. Zhang, T., Wang, W., Koukoulos, I. et al. (2025). *High frequency of moraine-dammed lake outburst floods driven by global warming*. Nat Commun 16, 11173. <https://doi.org/10.1038/s41467-025-67650-3>
4. Dhakal, B. (2026) *Bhote Koshi flood: A 360-degree look at causes, casualties, \$4.8 billion losses and climate justice push*. Nepal News. <https://english.nepalnews.com/s/explainers/bhote-koshi-flood-a-360-degree-look-at-causes-casualties-4-8-billion-losses-and-climate-justice-push/>
5. Gathen M, Welle K, Jaenisch M, Kasapovic A, Rommelspacher C, Novosel S, Roos J, Kabir K. (2022) *Are orthopaedic surgeons prepared? An analysis of severe casualties from the 2021 flash flood and mudslide disaster in Germany*. Eur J Trauma Emerg Surg. 48(5):4233-4241. <https://doi.org/10.1007/s00068-022-01967-2>