

# The Himalayan Hazard: Post-Event Assessment of the 2024 Thame Glacial Lake Outburst Flood in Everest Region, Nepal

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**Abstract:** Glacial Lake Outburst Floods (GLOFs) represent one of the most significant geomorphic hazards in the Hindu Kush Himalaya (HKH), where rapid glacier retreat, unstable moraine-dammed lakes, and steep mountain topography create high downstream risk. On 16 August 2024, a cascading GLOF occurred in Thame Valley, Solukhumbu District, Nepal, following a rock avalanche into Upper Ngole-Cho Lake. The displaced lake water overtopped into Lower Ngole-Cho, causing moraine dam failure and releasing approximately 0.5 million m<sup>3</sup> of water and sediment. The resulting debris-laden flood travelled through Thame Khola, severely damaging Thame Village, hydropower infrastructure, agricultural land, and transportation routes. This study presents a post-event geomorphic and geotechnical assessment conducted between November and December 2024. Field investigations revealed extensive channel incision, lateral bank erosion, sediment deposition, and widespread slope instability. Deep-seated retrogressive landslides developed within weak glacio-lacustrine deposits underlying Thame Village and continue to evolve during rainfall events. The study highlights the importance of valley morphology, sediment characteristics, and cascading geomorphic processes in amplifying GLOF impacts. Results emphasize that post-GLOF hazards may persist long after the flood event and require sustained monitoring and mitigation.

**Keywords:** GLOF, Thame valley, Himalaya, Glacio-lacustrine deposits, Landslides, Geomorphic hazards

## Introduction

Climate warming across the Hindu Kush Himalaya has accelerated glacier retreat and promoted the formation and expansion of moraine-dammed glacial lakes (Rounce et al., 2017). Many of these lakes are susceptible to failure triggered by avalanches, earthquakes, intense rainfall, or internal erosion. On 16 August 2024, a major GLOF occurred in the Thame Valley of the Everest region. The event was initiated when a rock avalanche entered Upper Ngole-Cho Lake, causing displacement waves that overtopped into Lower Ngole-Cho and breached its moraine dam. The resulting flood propagated downstream through the Thame Khola, causing severe geomorphic and infrastructural damage. Despite their relatively small size, the Ngole-Cho lakes generated significant

downstream impacts, demonstrating that hazard magnitude is controlled not only by lake volume but also by topographic and sedimentary conditions.

The objective of this study is to document the geomorphic evolution of the event, assess post-flood slope instability, and evaluate the role of valley-fill materials in controlling hazard persistence.

## Methodology

Thame Valley is located within the upper Dudh Koshi Basin of Solukhumbu District, eastern Nepal. The watershed extends from elevations exceeding 6,500 m near the Tashi Lapcha region to approximately 3,600 m at the confluence with the Bhote Koshi River. The valley contains numerous glacial lakes, including Upper and Lower Ngole-Cho, which were directly involved in the 2024 outburst. Thame Village is situated at approximately 3,800 m elevation on gently sloping glacio-lacustrine and deltaic deposits.

Post-event investigations were conducted from 30 November to 3 December 2024. The assessment included geomorphic mapping, geological observations, channel surveys, landslide investigations, and sampling of representative soils. Exposed channel sections created by flood erosion provided opportunities to examine subsurface stratigraphy and characterize glacio-lacustrine deposits. Laboratory testing was performed to determine index and strength properties of representative materials.

## Results and discussion

### Flood evolution and geomorphic impacts

The flood was generated by a cascading sequence of processes involving rock avalanche impact, lake overtopping, moraine dam breach, and downstream sediment entrainment. Field observations confirmed extensive erosion of moraine deposits and large-scale sediment mobilization. Upstream near Thambo, the flood interacted with an ancient landslide deposit, temporarily impounding water before rapid overtopping and incision produced a secondary surge. This process amplified downstream erosion and sediment transport.

Approximately 8–9 km downstream, Thame Village experienced severe geomorphic transformation. The Thame Khola channel was incised by as much as 10 m, while lateral erosion destabilized valley slopes and damaged buildings, agricultural land, and hydropower infrastructure. Thick deposits of boulders, cobbles, gravel, and sand accumulated across the valley floor, creating extensive debris fans and flood deposits.

### Post-GLOF slope instability

One of the most significant consequences of the event has been the development of progressive slope instability. Extensive tension cracks, ground settlement, and retrogressive landslides were observed on both sides of the valley. Some cracks extended several metres with measurable ground displacement of up to 40 cm. The largest active landslide continues to widen and retreat upslope during periods of intense rainfall.

Geological investigations indicate that Thame Village is underlain by weak glacio-lacustrine deposits composed predominantly of fine-grained silts and sands. These materials possess low plasticity and low residual shear strength when saturated. During the flood, rapid channel incision and bank undercutting altered stress conditions and increased susceptibility to slope failure. Elevated groundwater levels and continued rainfall have sustained instability long after the flood event.

### Implications for hazard assessment

The Thame event demonstrates the importance of cascading hazard mechanisms in Himalayan valleys. Similar to historic events such as the 1985 Dig Tsho GLOF, the disaster evolved through a chain of interconnected processes rather than a single triggering mechanism. The study indicates that valley morphology, sediment composition, and hydrological connectivity strongly influence flood behaviour and post-event hazard development. Furthermore, the event highlights limitations of current hazard prioritization approaches, as the source lakes were previously classified as low-priority despite producing significant impacts.

## Conclusions

The 2024 Thame GLOF was initiated by a rock-avalanche-induced breach between Upper and Lower Ngole-Cho lakes, releasing approximately 0.5 million m<sup>3</sup> of water and sediment. The resulting flood caused severe channel incision, widespread erosion, infrastructure damage, and extensive sediment deposition. Post-event investigations revealed that weak glacio-lacustrine deposits beneath Thame Village continue to undergo retrogressive landsliding and settlement due to their low residual shear strength and sensitivity to groundwater fluctuations. The study demonstrates that GLOF impacts are strongly controlled by valley confinement, sediment properties, and antecedent climatic conditions rather than lake size alone. Continuous monitoring, drainage management, and localized slope stabilization are therefore essential for reducing long-term risk in Thame Valley and similar Himalayan environments.

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## References

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