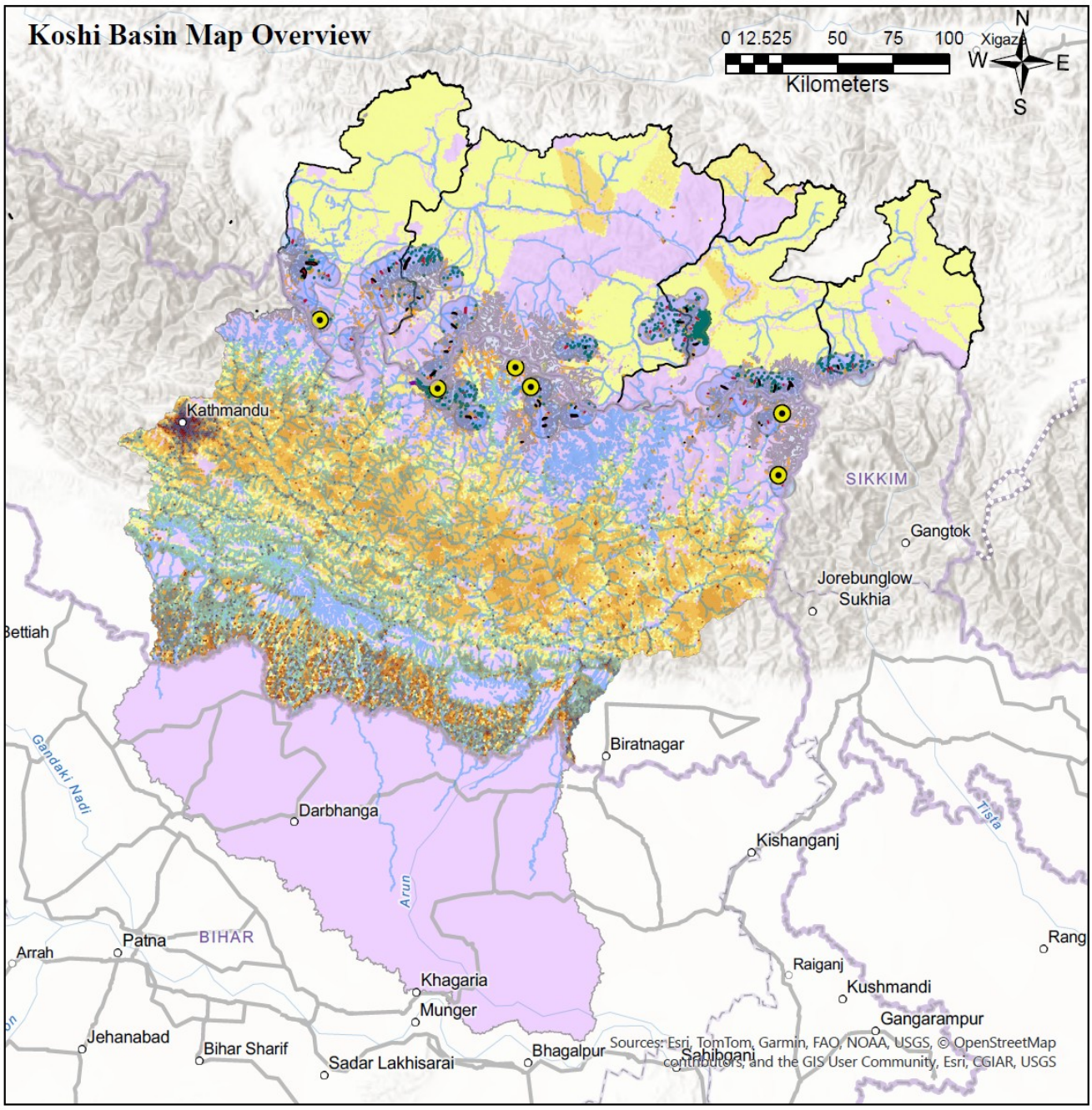
Glacial Lake Outburst Flood (GLOF) Risk Mapping — Koshi Basin, Nepal & China

A screening-level hazard and exposure assessment

Analysis & cartography: Zhenyi Tsai

Contents



Legend

- Recorded GLOF Events 1920 - 2020
- Koshi Glaciers
- Koshi Basin Boundary
- 5km Buffer Danger Zone
- China Counties In Koshi Basin
- At Risk Population Density per Sq KM

Koshi Lakes GLOF Risk Level

- High
- Medium

- Tsho Rolpa River
- Imja Khola River

China and Nepal Koshi Basin Population Density

population

- 1 - 8
- 9 - 10
- 11 - 17
- 18 - 39
- 40 - 109
- 110 - 333
- 334 - 1048
- 1049 - 3324
- 3325 - 10582
- 10583 - 33717

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August 2026

1. Abstract

In the climate-vulnerable Himalayan Region, the threat of Glacial Lake Outburst Floods (GLOFs) is rising rapidly due to accelerated glacial retreat and melting permafrost. GLOFs are among the most destructive climate-driven hazards in High Mountain Asia. As climate change accelerates glacial melt, meltwater pools behind unstable natural dams; when these dams fail, the lake releases catastrophically and the resulting flood can travel tens of kilometres down-valley, threatening communities far downstream. This project was of personal interest because of people I know who have suffered the devastating flood in Gyirong, on the Chinese side of the Nepal-Tibet border. The hope for this project is to clearly visualize High-risk areas for future GLOFs in the Koshi Basin.

Using spatial analysis and map creation in ArcGIS Pro, this project develops a transparent, multi-criteria screening model to identify and rank the outburst risk of glacial lakes across China and Nepal's Koshi basin. I analyze the highest-risk basin in the country and then quantify human exposure both near the lakes and along their downstream flood paths. Results reveal from a 5km buffer of 79 high-risk glacial lakes that approximately 10,808 people are situated in the danger buffer. Moreover, downstream geography determines who is exposed by potential GLOF the major rivers Imja Tsho and Tsho Rolpa Imja's corridor has more settlements (20) but fewer people (~224), while Tsho Rolpa's has fewer settlements (9) but roughly five times the population (~1,134). Although these results are concerning it is important to note that due to the nature of remote sensing spatial analysis there are certain limitations of to-date accuracy compared to on the ground field surveying.

2.Objective

1. Classify the outburst risk of every glacial lake in the Koshi basin using open data and a defensible, physically grounded method.
2. Validate the model against an independent, authoritative hazard inventory.
3. Quantify downstream human exposure — moving beyond simple proximity to trace where floods would actually travel.
4. Formally map out potentially at-risk communities and populations.

3. Data

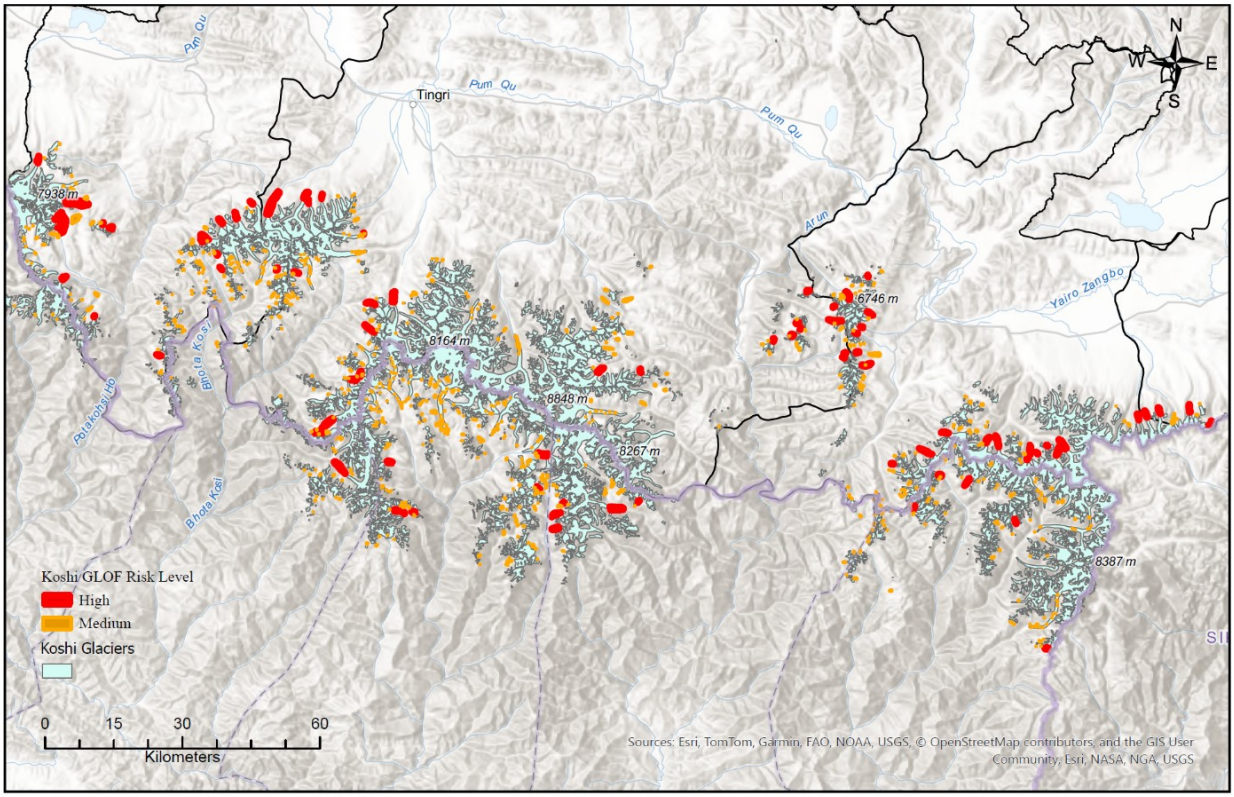
All layers are drawn from open, authoritative sources. Distance and area analysis were performed in a projected coordinate system (WGS 1984 UTM Zone 45N); web layers were reprojected to geographic / Web Mercator.

Layer	Source
Glacial lake inventory (~2,000 lakes)	ICIMOD — Koshi/Gandaki/Karnali basins
Glacier outlines	Randolph Glacier Inventory (RGI) 7.0

Layer	Source
Historical GLOF events (1533–2025)	ICIMOD HMA GLOF database
Potentially dangerous lakes (validation)	ICIMOD PDGL inventory (47; 42 in Koshi)
Population	Kontur population density (400 m hexagons)
Settlements	OpenStreetMap populated places (HDX)
Rivers	OpenStreetMap waterways (HDX)
Basin boundary	ICIMOD Koshi River Basin boundary

4. Method

4.1 Risk model



Glacial Lake Outburst Flood Risk: Koshi Basin, Nepal

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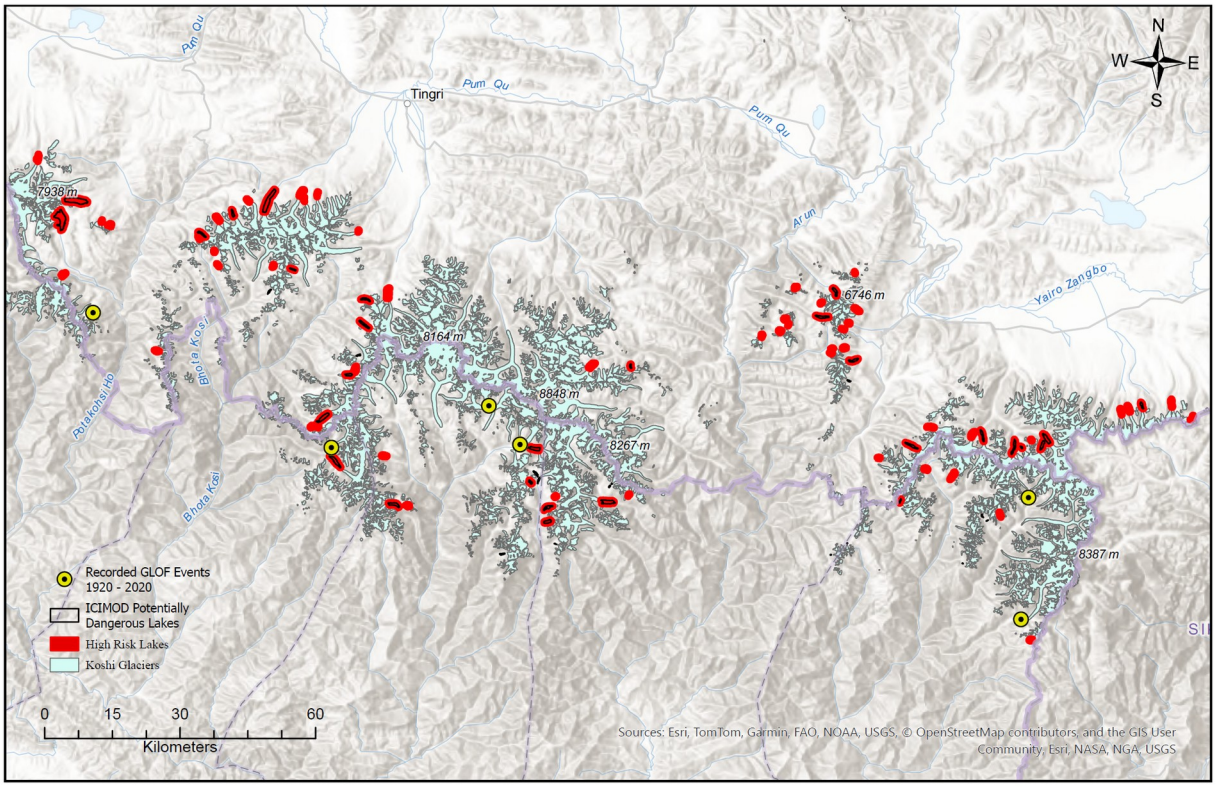
Description: Screening assessment of ~2,000 glacial lakes in Nepal's Koshi basin identified 79 as high-risk and 860 medium-risk for outburst flooding. Each lake was scored on dam type, surface area, and proximity to glacier ice — the three factors most associated with historical GLOF events. High-risk lakes cluster along the glaciated spine of the basin, concentrated in the Everest (Dudh Kosi), Rolwaling (Tama Kosi), and eastern (Arun) sub-basins.

Each of approximately 2,000 glacial lakes was scored on three independent, physically grounded factors, each contributing one to three points:

- **Dam type** — moraine-dammed lakes, held by loose and failure-prone debris, score highest; ice and supraglacial lakes score moderate; bedrock and erosion lakes score lowest.

- **Lake area** — a proxy for potential flood volume; larger lakes score higher.
- **Proximity to glacier ice** — lakes in contact with ice are exposed to the classic avalanche-into-lake trigger mechanism. Computed using the Near tool in a metric projection.
- The three scores were summed into a composite index (range 3–9) and classified as High, Medium, or Low. Thresholds were calibrated so that the High class flags a manageable, credible shortlist rather than over-warning. The model identified 79 high-risk lakes.

4.2 Validation



Model Validation Against ICIMOD Potentially Dangerous Lakes: Koshi Basin, Nepal

Credits: Created by Zhenyi Tsai
August 2026

Description: Model validation against ICIMOD's authoritative inventory of 42 potentially dangerous glacial lakes (PDGLs) in the Koshi basin. The independent screening model captured 29 of the 42 recognized PDGLs (69%), including the benchmark Rank-I lakes Imja and Tsho Rolpa — a strong result for a lightweight, three-factor approach (dam type, lake area, and glacier proximity). Lakes flagged by only one method mark where rapid screening and detailed field assessment diverge, making the two complementary tools for GLOF hazard prioritization.

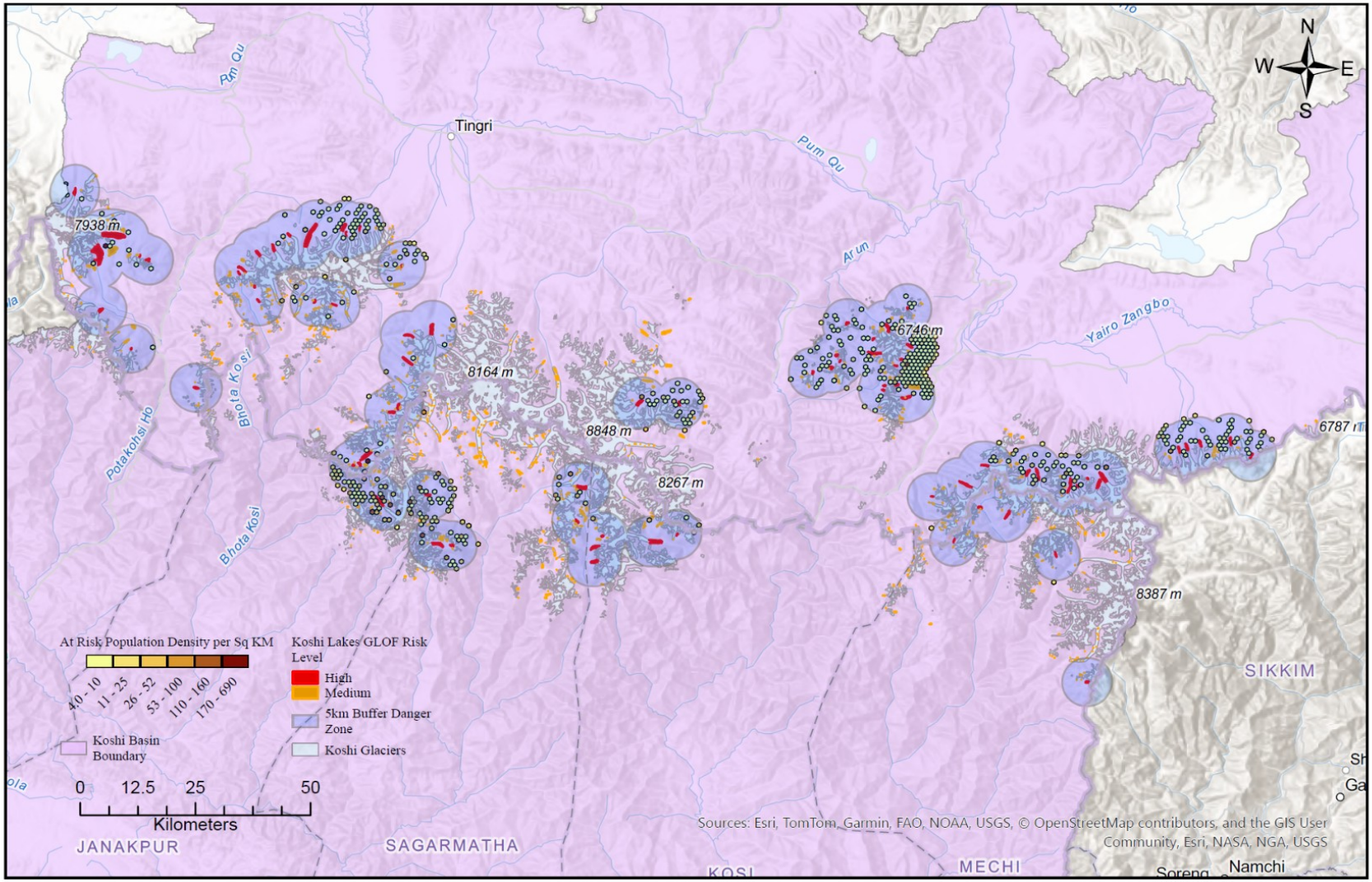
The **79 high-risk** lakes were compared against ICIMOD's independent inventory of 42 potentially dangerous glacial lakes (PDGLs) in the Koshi basin. The screening model captured 29 of the 42 (69%), including both Rank-I benchmark lakes, Imja Tsho and Tsho Rolpa; a strong result for a lightweight, three-factor approach. Divergences mark where rapid screening and detailed field assessment complement one another.

4.3 Exposure analysis

Phase A —Proximity. A 5 km buffer around the **79 high-risk** lakes defined an immediate danger zone containing approximately **10,808 people**. Because the high-risk lakes sit in remote upper catchments, this figure is a deliberately conservative baseline.

Phase B — Downstream flow paths. Flood corridors were traced along the river network from two priority lakes and buffered as screening corridors. The results reveal that the same hazard carries very different human consequences depending on downstream geography:

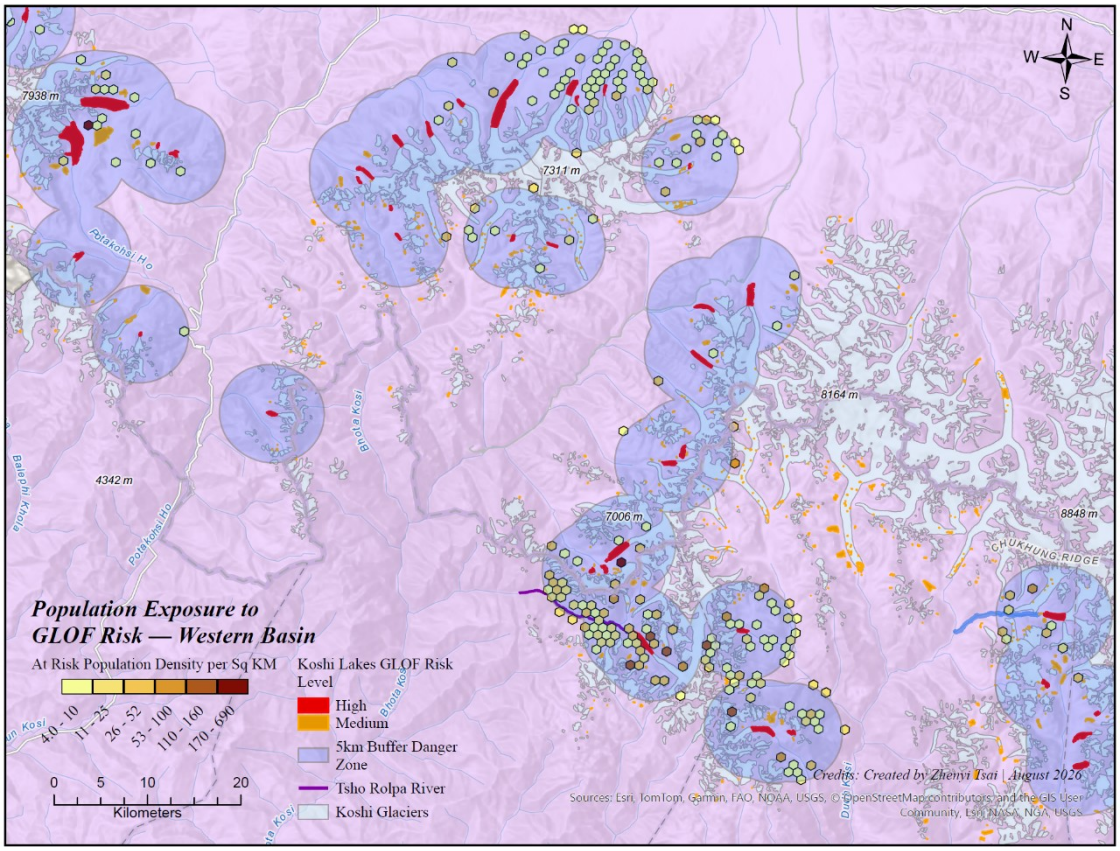
Corridor	River path	Settlements	Modeled residents
Imja Tsho	Imja Khola → Dudh Kosi	20	~224
Tsho Rolpa	Rolwaling Khola → Tama Kosi	9	~1,134

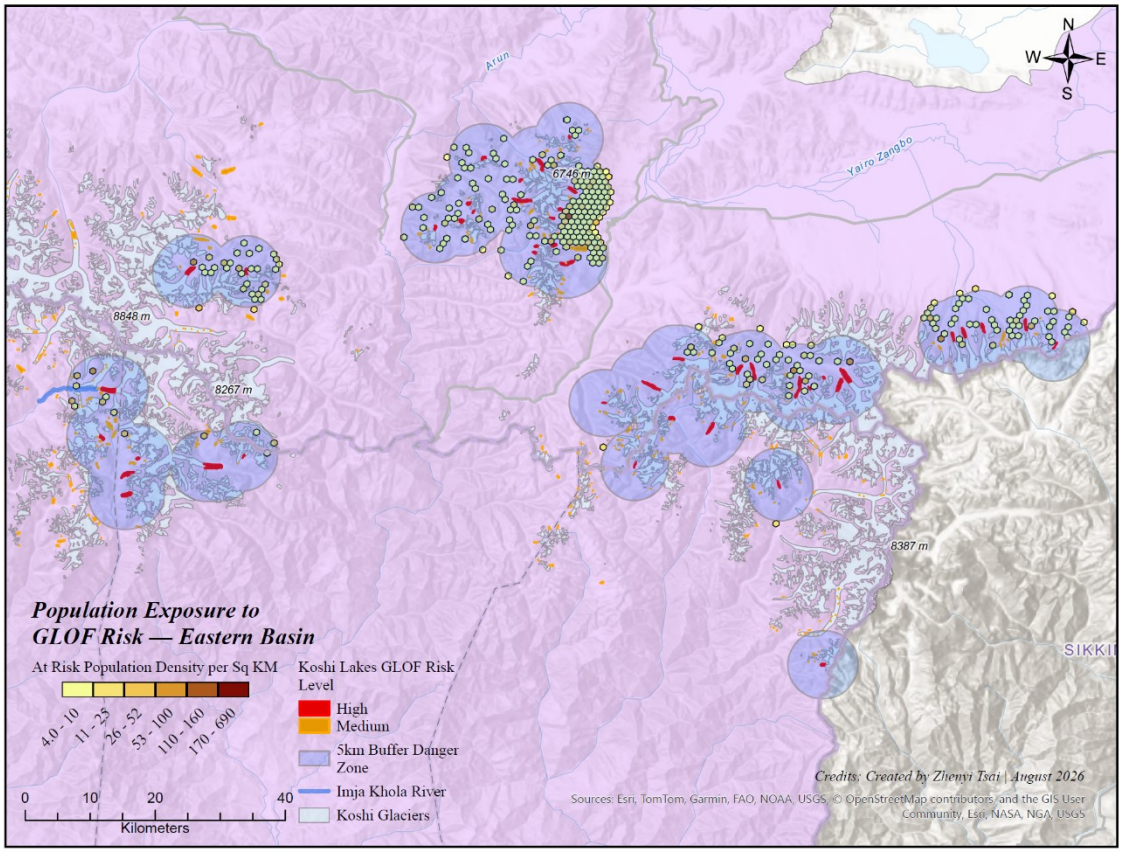


Population Exposure to GLOF Risk — Koshi Basin, Nepal

Credits: Created by Zhenyi Tsai
August 2026

Description: Proximity-based exposure analysis. A 5 km danger zone around the 79 high-risk glacial lakes contains approximately 10,808 people, shown as population-density hexagons. Exposure concentrates in sparsely populated high-mountain valleys near the glacier belt. Because most high-risk lakes lie in remote upper catchments, this proximity figure is a conservative baseline — outburst floods travel far beyond 5 km down-valley, so downstream flow-path analysis (companion map) reveals substantially greater exposure.


N
W
E
S
7938 m
7311 m
8164 m
4342 m
7006 m
8848 m
CHUKHUNG RIDGE
Potakonsi Ho
Bhota Kosi
Population Exposure to
GLOF Risk — Western Basin
At Risk Population Density per Sq KM
4.0 - 10
11 - 25
26 - 52
53 - 100
110 - 160
170 - 690
0 5 10 20
Kilometers
Koshi Lakes GLOF Risk Level
High
Medium
5km Buffer Danger Zone
Tsho Rolpa River
Koshi Glaciers
Credits: Created by Zhenyi Tsai | August 2026
Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, Esri, NASA, NGA, USGS


N
W
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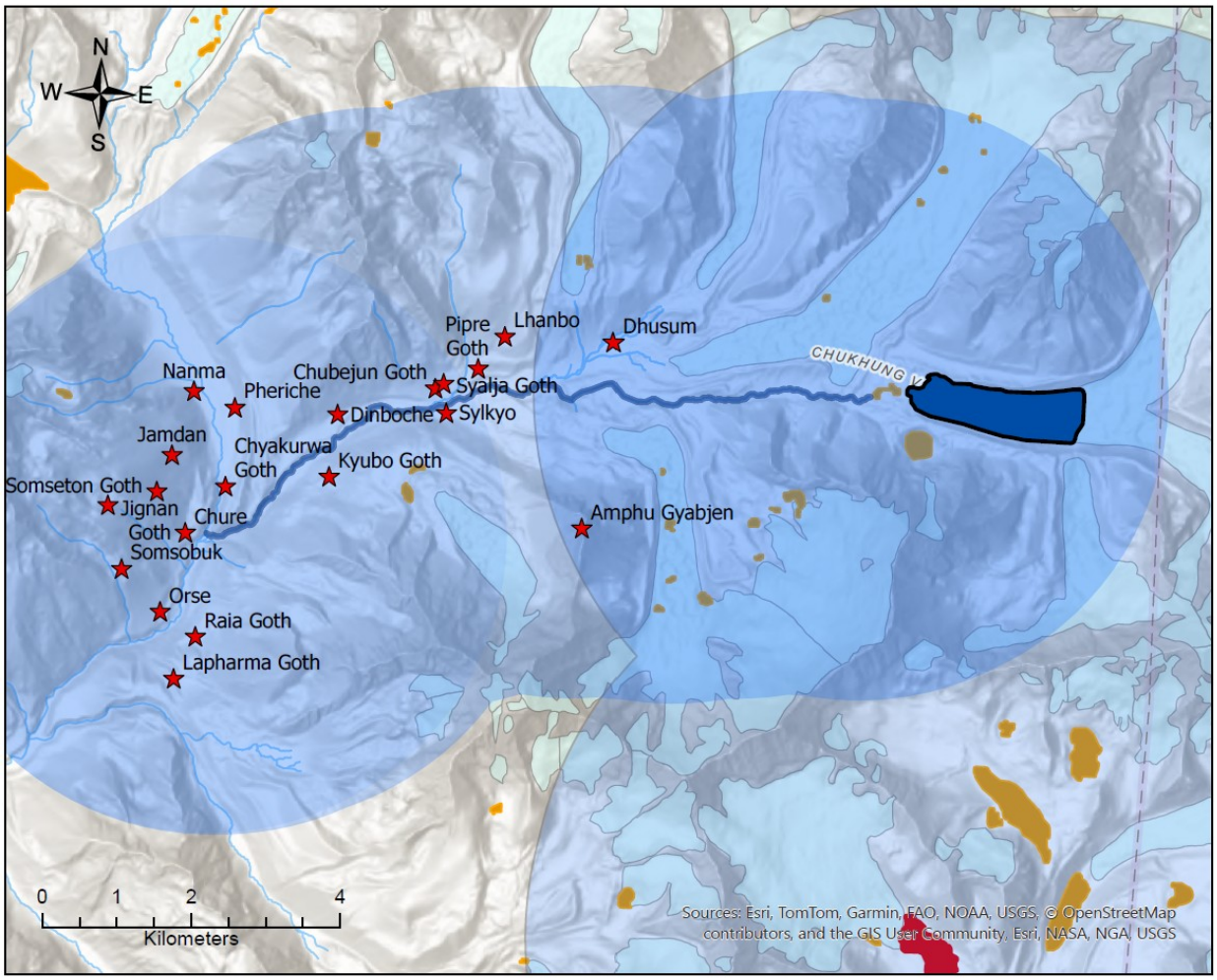
Arun
Yairo Zangbo
6746 m
8848 m
8267 m
8387 m
SIKKIM
Population Exposure to
GLOF Risk — Eastern Basin
At Risk Population Density per Sq KM
4.0 - 10
11 - 25
26 - 52
53 - 100
110 - 160
170 - 690
0 10 20 40
Kilometers
Koshi Lakes GLOF Risk Level
High
Medium
5km Buffer Danger Zone
Imja Khola River
Koshi Glaciers
Credits: Created by Zhenyi Tsai | August 2026
Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, Esri, NASA, NGA, USGS



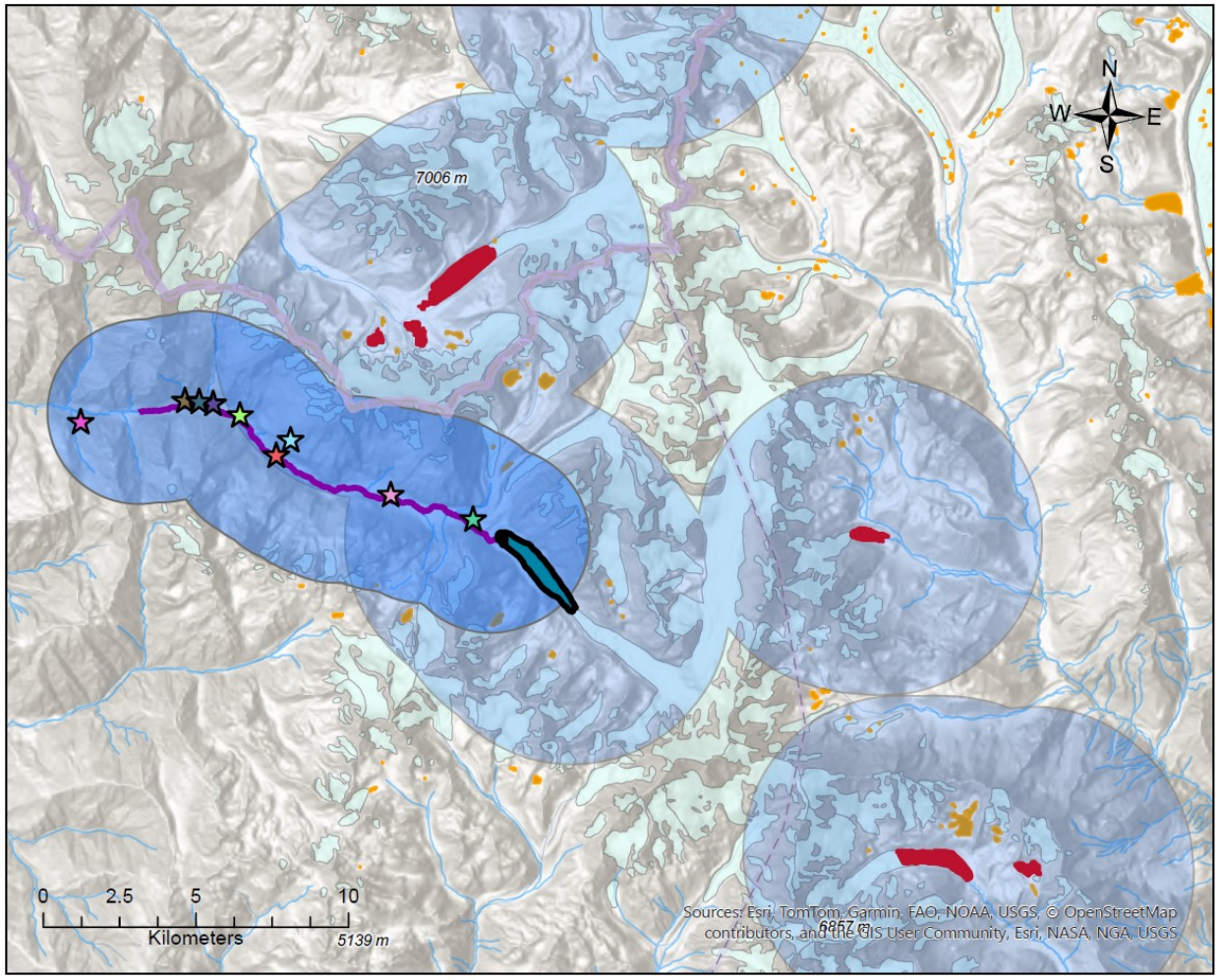
Imja Flood Corridor — Downstream Exposure, Koshi Basin

Downstream flow-path analysis of Imja Tsho, a Rank-I potentially dangerous glacial lake in the Khumbu. Tracing the flood corridor along the Imja Khola into the Dudh Kosi, the path intersects 20 settlements, yet only ~224 modeled residents, far fewer people than Tsho Rolpa's corridor despite more villages. This is because the upper Khumbu is sparsely and seasonally populated. The contrast shows how the same hazard carries very different human consequences depending on downstream geography.

Note: population grids under-record high-altitude settlements, so the settlement count better reflects Imja's true exposure than the modeled figure. Corridor shown as a screening buffer along the river network, not modeled inundation.

Imja Khola Settlements
Imja Flood Buffer 3km
Koshi Lakes GLOF Risk Level
Koshi Glaciers
Dudh Koshi Lake
High
Imja Khola River
Medium

Credits: Created by Zhenyi Tsai
August 2026



Tsho Rolpa Flood Corridor — Downstream Exposure, Koshi Basin

Downstream flow-path analysis of Tsho Rolpa, a Rank-I potentially dangerous glacial lake. Because outburst floods travel far down-valley, exposure extends well beyond the lake itself. Tracing the flood corridor along the Rolwaling Khola into the Tama Kosi, the path threatens 9 settlements and approximately 1,134 residents in the lower valley. This demonstrates that downstream flow-path analysis reveals substantially greater and more concentrated exposure than proximity alone. Corridor shown as a screening buffer along the river network, not modeled inundation.

Legend

- Tama Koshi Lake
- 5km Buffer Danger Zone
- Tsho Rolpa River
- Tsho Rolpa Flood Risk Buffer
- Koshi Glaciers
- Koshi Lakes GLOF Risk Level
  - High
  - Medium
- Settlements at Risk
  - Beding
  - Chhimu Golche
  - Dhogre
  - Ghokrekharka
  - Jobalu
  - Nagaun
  - Ramding
  - Sanmakharka
  - Thangthikharka

Credits: Created by Zhenyi Tsai
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5. Key findings

- **A simple, transparent model works.** Three open-data factors independently identified 69% of the officially recognised dangerous lakes in the basin.
- **Proximity understates risk.** Only ~10,808 people live within 5 km of a high-risk lake, but GLOFs travel far down-valley, the flood corridors reach populations well beyond that immediate zone.
- **Downstream geography determines who is exposed.** Imja's corridor has more settlements (20) but fewer people (~224), while Tsho Rolpa's has fewer settlements (9) but roughly five times the population (~1,134).
- **Population grids under-record high-altitude settlements.** In the upper Khumbu, settlement count is a more reliable exposure indicator than modeled population, an important data-limitation insight.

6. Deliverables

- **Map 1 — Risk:** the 79 high-risk lakes across the glaciated spine of the basin.
- **Map 2 — Validation:** model output versus ICIMOD's 42 PDGLs (29 matches, 69%).
- **Maps 3-5 — Exposure (Phase A):** a three-panel figure (regional, western, eastern) showing population within the 5 km danger zone.
- **Maps 6-7 — Flood corridors (Phase B):** a two-panel figure contrasting the Imja and Tsho Rolpa downstream corridors and their at-risk settlements.
- **GitHub – Data Assets:** project layers, project geoprocesses and referenced external datasets. Link: https://github.com/zhenyijr/Koshi-GLOF

7. Limitations

- The risk index is a **screening tool**, not a hydrodynamic model; it ranks relative risk to prioritise lakes for detailed investigation.
- Flood corridors are **screening buffers along the river network**, not modeled inundation extents (which would require hydraulic modelling such as HEC-RAS).
- Population figures rely on gridded data that **under-records seasonal high-altitude settlements**; settlement counts supplement this in the upper catchments.
- **Equal weighting** of the three risk factors is a deliberate, transparent choice; field-based assessments may weight dam stability and proximity more heavily.

8. Significance

This workflow offers a rapid, low-cost, and reproducible method for prioritising which glacial lakes warrant detailed field investigation and monitoring, and for identifying the specific

downstream communities most exposed. It demonstrates an end-to-end hazard analysis, from open-data acquisition through spatial modelling, independent validation, exposure assessment, and cartographic and web-based communication — across ArcGIS.

Based on these findings I emphasize the joint efforts of both Nepal and China for integrated disaster management for smooth connectivity between two countries and saving downstream population through joint cooperation from central government to local community-based levels by initiating artificial lake lowering, developing cross-border early warning systems and cooperation. This project is valuable for presenting a synergistic overview of glacial lakes and GLOF for informing anyone engaging in disaster mitigation, research or general concerned interest of the climate risks in the Koshi Basin.

Data: ICIMOD, Randolph Glacier Inventory 7.0, Kontur, HydroSHEDS, OpenStreetMap. Basemap: Esri, NASA, NGA, USGS.