# Bhote Koshi/Sun Koshi River, Nepal

## Potential GLOF risk assessment and management

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Based on two different flood scenarios, the value of property at risk of potential GLOF in the Bhote Koshi/Sun Koshi basin – a trade route with well-developed infrastructure – is estimated to range from USD 153 million to USD 189 million. Infrastructure development planning is necessary to prevent such high loss of property.

## Introduction

The Bhote Koshi is a transboundary river originating on the southern slopes of the Himalayas in the Tibet Autonomous Region of China (Figure 2). This river is called the Poiqu (Boqu) in Tibet, the Bhote Koshi in Nepal from the Nepal-China border (Friendship Bridge) down to the confluence with the Sun Koshi at Barhabise, and the Sun Koshi downstream from this confluence. Twenty-four GLOF events have been reported in Nepal, ten of which occurred in the Tibetan catchments of rivers flowing into Nepal (ICIMOD 2011). The Bhote Koshi/Sun Koshi River experienced three such GLOF events: in 1935, 1964, and 1981. The 1981 GLOF caused heavy loss of life, property, and infrastructure. The maximum discharge was estimated at 15,920 $m^3$ per second 23 minutes after bursting and the bursting flood lasted for an hour. Approximately 19 million cubic metres of burst water was discharged, 16 times more than the average annual flood in this river. Nearly 4 million cubic metres of debris was carried in the floodwaters as sediment in a moving layer ranging from 4 to 10 m thick (Xu 1985). The 1981 GLOF event swept away five people, 41 houses, two highway bridges, and many water mills. About 27 km of road were severely damaged. The total loss was estimated at NPR 11 million (about USD 750,000 at the 1981 conversion rate). Trade and traffic flow between Lamosangu (the start of the Lamosangu-Jiri road) and the market centre of Barhabise was blocked for 36 days and transport services between Barhabise and Kodari were disrupted for three years.

In the Bhote Koshi/Sun Koshi basin, 139 glacial lakes and nine lakes have been identified as potentially dangerous (Figure 3). Time series analysis shows that the number, area, and ice reserves of glaciers in this basin are declining, but that the number of glacial lakes and their area are increasing (Mool et al. 2005). One study warns that GLOFs with surges double the magnitude experienced in 1981 are likely to occur in the future in the Bhote Koshi/Sun Koshi River (WECS 1987). As the risk of GLOF in this basin is likely to increase in the future, this study was carried out to:

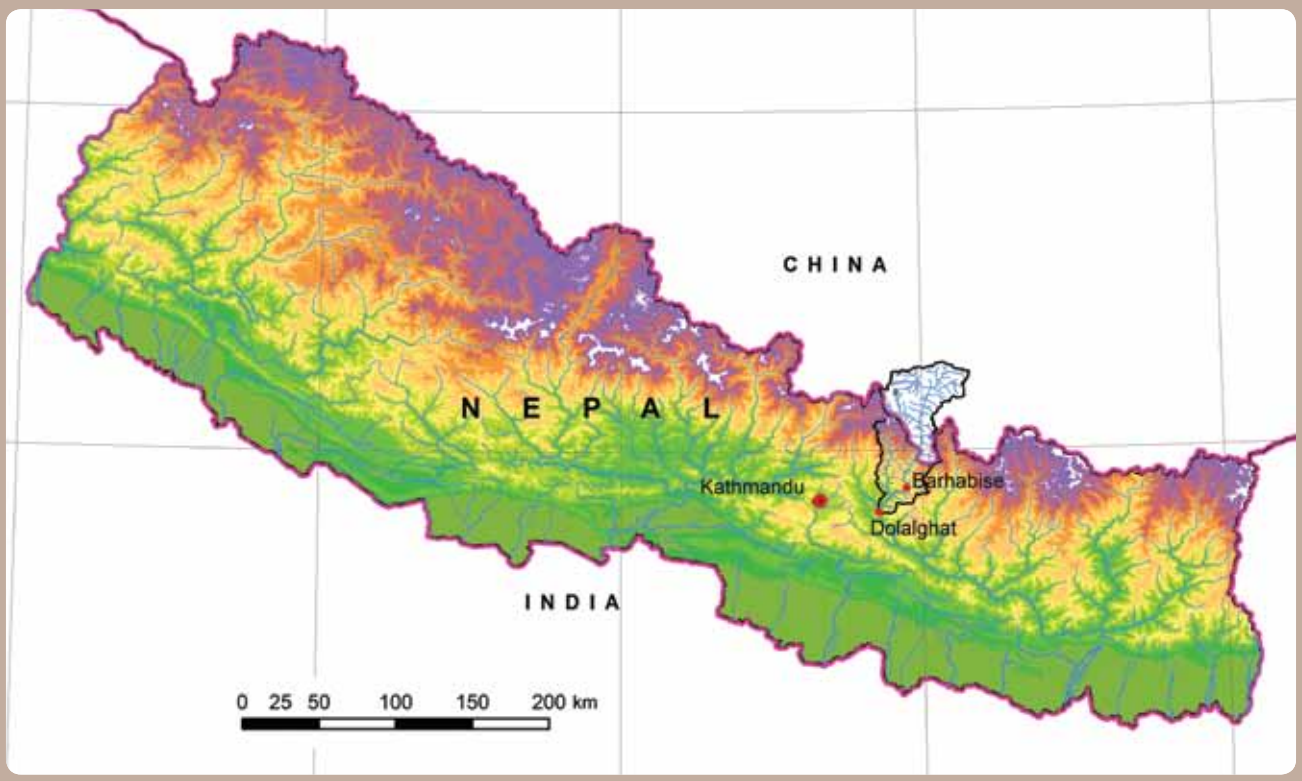
- review past GLOF events in terms of magnitude, loss, and damages and the rescue and relief activities conducted;
- identify and quantify (including in monetary terms) the elements exposed to GLOFs; and
- assess the perceptions and capacity of local people and identify their needs for capacity enhancement.

## Methodology

The 1981 GLOF event was taken as a baseline event for the purposes of the study. The study area is along the Bhote Koshi/Sun Koshi valley from the Nepal-China Friendship Bridge on the border between Nepal and China in the north to Dolalghat in the South.The Bhote Koshi/Sun Koshi River was divided into ten blocks, each incorporating at least one major settlement.

Two flood scenarios were used to assess the potential GLOF risk. The first was the flood level experienced during the 1981 GLOF. Local people were asked to mark the 1981 flood level in different places and

Figure 2: **Map of Nepal with the Bhote Koshi/Sun Koshi basin**




those areas were delineated in topographical maps. The second scenario was subjectively fixed at 10 m higher than the 1981 level and those areas that would be affected by a flood of this magnitude were also delineated in topographical maps.

At least one meeting was held with key informants in each block to gather information. Discussions with wholesale agents, personnel of the Tatopani Customs Office, and local traders were also conducted to collect information on trade and traffic flow and their impact on employment and livelihoods.

Per unit cost was used to estimate the monetary value of potential loss. The value of individual property was calculated and added together to give a figure for total potential loss. Local prevailing purchase values were used for household assets (land, crops, and livestock) and replacement costs were used for infrastructure.

After preparation of a draft report, a one-day risk communication workshop was organized at the township of Barhabise. Local people from each block were invited to attend the workshop and share their perceptions and experiences.

Figure 3: **Major glacial lakes and potentially dangerous lakes in the Bhote Koshi/Sun Koshi basin**

## Findings

Nearly 900 households with a corresponding population of 5,800 will be directly affected if a GLOF of the same magnitude as the 1981 GLOF occurs in the Bhote Koshi/Sun Koshi River as they are living within the GLOF hazard zone or their properties are within the hazard zone. This figure will increase to 2,519 households with a corresponding population of 16,313 people if GLOF is 10 m higher than the 1981 GLOF (Table 2).

The major ethnic/caste groups exposed to flash flood risk in the area are Sherpa, Tamang, Thami, Newar, Majhi, Chhetri, Bahun, and Dalit. Of these groups, Majhi and Thami are defined by the National Committee for Development of Nationalities as highly marginalized, Tamangs are categorized as marginalized, and Sherpas as a disadvantaged indigenous ethnic group. Nearly 50 per cent of families exposed to risk are poor and up to 30 per cent ultra poor. Poor, marginalized, and disadvantaged groups generally have less access to resources and decision-making processes, making them highly vulnerable to disasters including flash floods.

A GLOF in the area would affect the flow of vehicles, goods, and people along the Lamosangu-Jiri road, spreading the indirect impact to many village development committees (VDCs) in Dolakha, Ramechhap, and Solukhumbu districts (Figure 2). As per the population census of 2001, a total of 639,000 people are likely to be indirectly affected by damage to the Arnico Highway and Lamosangu-Jiri road (Central Bureau of Statistics 2001). Many more people involved in international trade with China and tourism activities to Tatopani and the Khumbu region are also likely to be affected.

The livelihood support system of more than 3,800 families living inside and outside the GLOF hazard areas is likely to be severely affected including wholesale and retail traders, hotels, industry, transport services, government services, and tourism. The Sun Koshi River is one of the world's top ten rafting rivers, with about six rafting spots along a 28 km reach of the river. A GLOF would affect seven hotels and numerous rafting operators, river guides, and tourism operators that serve the rafting tourism industry along this river.

The transport sector is also likely to be affected. More than 60 jeeps, 50 buses and minibuses, and 60 trucks shuttle daily along the Arnico Highway. This flow will be disturbed. Tatopani, which is located near the Nepal-China Friendship Bridge, is an international trade hub with China. The volume of international trade, including the amount of revenue collected by the government, will be affected by GLOF damage to bridges and roads and the consequent disruption in the flow of goods and services.

The estimated total value of property at risk of GLOF is USD 153 million under scenario 1 (a GLOF level the same as 1981) and USD 189 million under scenario 2 (a GLOF level 10 m higher than 1981). There will be a drastic increase in the share of private property (buildings, land, crops) and roads affected

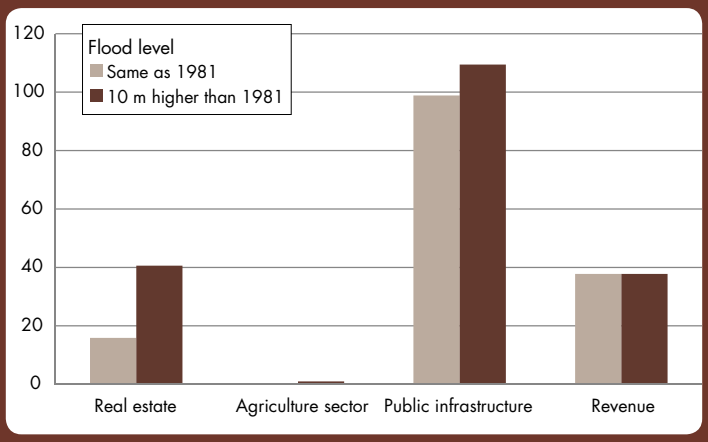
Table 2: **Elements exposed to potential GLOF event on the Bhote Koshi/Sun Koshi River**

| Element exposed | GLOF level | |
|---|---|---|
| | Same as 1981 GLOF | 10 m higher than 1981 GLOF |
| Households (number) | 866 | 2,519 |
| People (number) | 5,782 | 16,313 |
| Irrigated land (ha) | 28.3 | 102.1 |
| Unirrigated land (ha) | 7.9 | 64.4 |
| Housing plots (ha) | 5.1 | 21 |
| Paddy (tonnes) | 122.5 | 384.5 |
| Wheat (tonnes) | 23.8 | 94.5 |
| Maize (tonnes) | 72.9 | 258.5 |
| Millet (tonnes) | 13.8 | 82.4 |
| Potatoes (tonnes) | 1.5 | 53.2 |
| Fruit (tonnes) | 27.3 | 81.7 |
| Vegetables (tonnes) | 166.3 | 586.8 |
| Livestock (number) | 1,005 | 2,620 |
| Concrete houses (number) | 248 | 586 |
| Non-concrete houses (number) | 483 | 1,527 |
| School buildings (number) | 6 | 13 |
| Office buildings (number) | 15 | 17 |
| Temples (number) | 7 | 10 |
| Roads (km) | 24 | 36.5 |
| Trails (km) | 1.4 | 20.5 |
| Embankments (km) | 5 | 5 |
| Highway bridges (number) | 2 | 7 |
| Suspension bridges (number) | 15 | 23 |
| Hydropower plants (number) | 3 | 3 |
| Water mills (number) | 4 | 11 |
| Transmission lines (number) | 14 | 24.5 |
| Drinking water supply pipeline (km) | 3.5 | 7.5 |
| Fibre cable line (km) | 5.5 | 8.5 |

under scenario 2 (Figure 4). The estimated total value of property at potential risk under scenario 1 is more than 153 times higher than the estimated loss experienced during the 1981 GLOF. This difference is partly due to the fact that there is now a lot more infrastructure in the area, including the Bhote Koshi Hydroelectricity Project, Power House of Sanima Hydroelectricity Project, and a fibre cable line along the road, and partly due to the fact that the total estimated value lost during 1981 was based on actual loss, which is far less than the potential loss.

Nearly 50 per cent of the property (in terms of monetary value) likely to be damaged is located in the Hindi area followed by Khandichaur (21 per cent), Lipin (17 per cent), and Barhabise (7 per cent), where major infrastructure development and economic activities are concentrated (Figure 5).

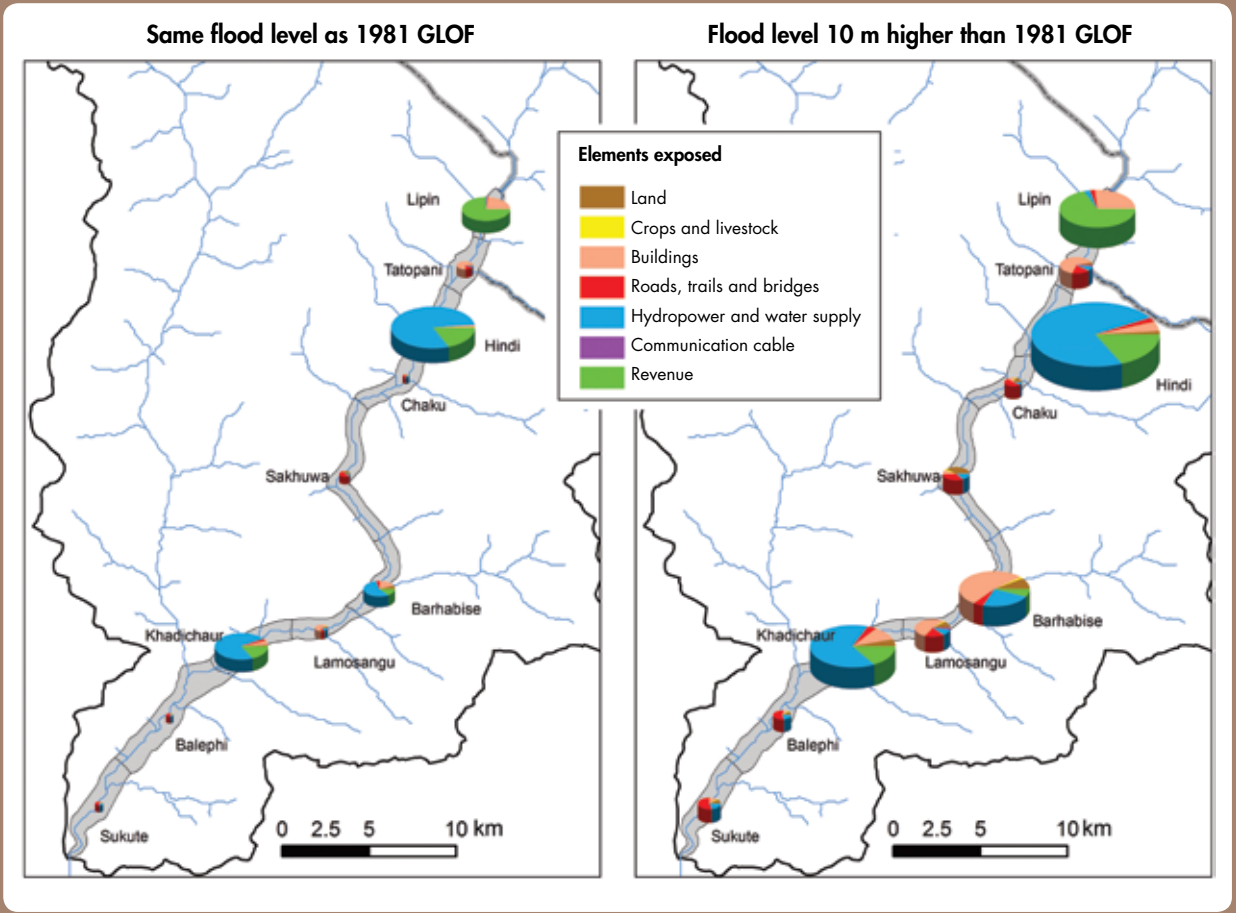
Figure 4: **Property at risk of GLOF in the Bhote Koshi/Sun Koshi basin, Nepal (million USD)**




## Lessons for Risk Management

Local people are aware of the risk of GLOF and flash flood as they have experienced two major floods in the recent past: the GLOF event of 1981, which caused massive damage from the China-Nepal Friendship Bridge to Khandichaur downstream, and the cloudburst flood of 1987, which also caused heavy damage between Barhabise and Sukute. Many are also aware of the different mitigation measures necessary to reduce losses, such as early warning systems; rescue and relief operations; the establishment of shelters with food, water, clothing, sanitation, and health services; the construction and

Figure 5: **GLOF risk map of the Bhote Koshi/Sun Koshi basin, Nepal**




Note: The size of the pies are representative of the relative population size.

maintenance of embankments; and the formulation and enforcement of land use guidelines and building codes. But the implementation of such measures is limited because of poor technical and managerial knowledge about such measures combined with a lack of financial resources, institutional arrangements, and legal provisions.

An early warning system has been installed on the Bhote Koshi/Sun Koshi River by the Bhote Koshi Hydroelectricity Project. Five sensors are placed near the Nepal-China Friendship Bridge and automatic sirens have been placed in four different locations. The system is tested every three months and is fully functional. People living in those localities have been trained by the project, and signboards about the siren system have been erected in various localities. However, there is no warning system downstream for the powerhouse site at Hindi and there are no sensors in the upper reaches of the river in Tibet, China. For there to be enough lead time for evacuation, transboundary cooperation is necessary to monitor glacial lakes and develop an effective early warning system as all of the glacial lakes at risk of potential GLOF in this basin are located on the Chinese side of the border. A real-time data sharing mechanism is also essential.

After the 1981 GLOF, several mitigation measures were introduced. The road alignment was changed in several places from the flood plain/fan area to higher up the mountain slopes, and bridges were reconstructed and their design changed from truss to arch. Emphasis was placed on bioengineering and hill slope runoff management for the stability of toe slopes. River embankments were also constructed in several places to protect roads and settlements from flash floods including GLOFs.

Although different government and non-governmental institutions are involved in disaster risk reduction, their activities are limited and mainly focus on structural measures. There is no local-level institution focusing on disaster management in a holistic way to link upstream and downstream communities. There is also no institution responsible for the planning and safe development of human settlements along the road/riverbank, and land use guidelines and building codes are not enforced. In the absence of such control mechanisms, more and more settlements and infrastructure are being built in areas exposed to GLOFs.

There is no separate policy for managing GLOF risk in Nepal. However, some national policies do contain strategies and programmes to reduce the risk of GLOF. Many of these policies have adopted an integrated water resource management and river basin management approach with emphasis on community-based risk management. All these policies have programmes for the mapping and assessment of risk and vulnerability; establishment of early warning systems; development of non-structural measures such as flood forecasting and warning, floodproofing, and disaster preparedness; implementation of preventive measures; community sensitization and capacity development for risk management; development and strengthening of bilateral and multilateral cooperation in transboundary areas; land use and settlement planning; community-based disaster risk management planning; emergency response; and analysis of disasters to draw lessons to allow faster and effective deployment in case of disasters. The monitoring of potential GLOF lakes, implementation of structural measures, establishment of early warning systems, forecasting and preparedness in downstream communities, and support to vulnerable communities are some of the recommended programme activities in the NAPA and the Climate Change Policy, 2011.

## Recommendations

- Extend the existing early warning system to the downstream reaches of the river (as far as Dolalghat) and adjoining areas to cover the entire area at risk of GLOF.
- Raise awareness among local people of the probability and magnitude of GLOF risk in the area and provide them with skill development training for preparedness planning and rescue and relief operations.
- Formulate a preparedness plan for GLOF risk reduction together with local communities.
- Strengthen regional, national, and local capacities for GLOF risk reduction through awareness creation and skill development activities.
- Establish an emergency fund and community shelter with provisions for food, clothing, drinking water, and health services.
- Develop and implement land use guidelines and building codes together with the local community.
- Integrate and coordinate road network development, land use planning, and settlement and market centre development with disaster risk reduction activities.
- Form a transboundary (Nepal-China) team to conduct field investigations on glacial lakes and the river channel to determine the probability and potential magnitude of a GLOF in the Bhote Koshi/Sun Koshi basin towards developing a flood forecasting model and an early warning system with enough lead time to enable evacuation.
- Establish a network of institutions dealing with disaster risk reduction at the regional/transboundary, national, and local levels to share information on GLOF risk.
- Establish institutions that focus on flash flood management with dense community networks.