

# Hazard Zonation for Glacial Lake Outburst Flood (GLOF) in Bhutan Himalaya

A mode of Adaptation to the impacts of  
climate change

DGM-NCAP Project

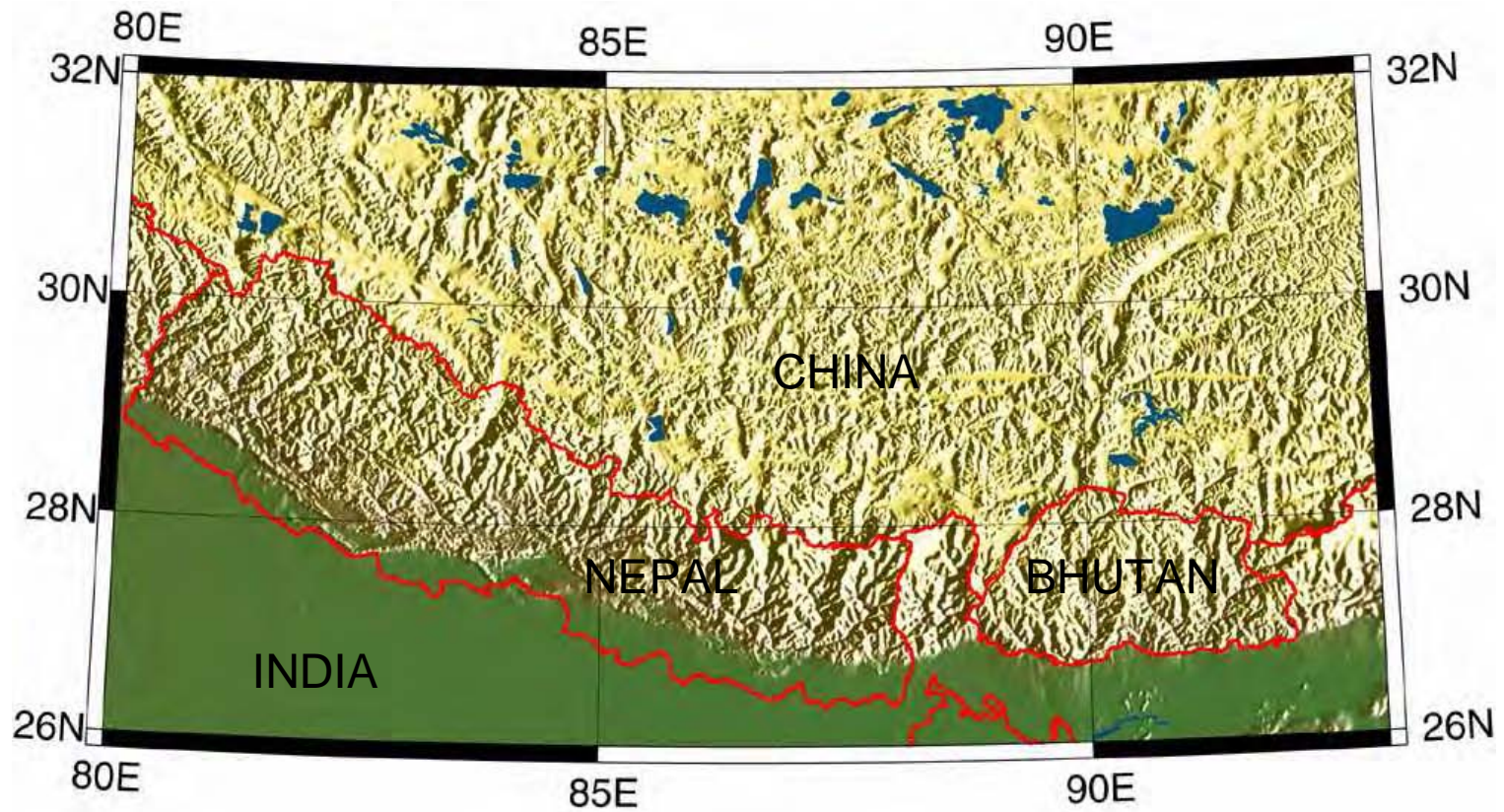
Karma

Department of Geology & Mines

Ministry of Economic Affairs

Royal Government of Bhutan

# Location

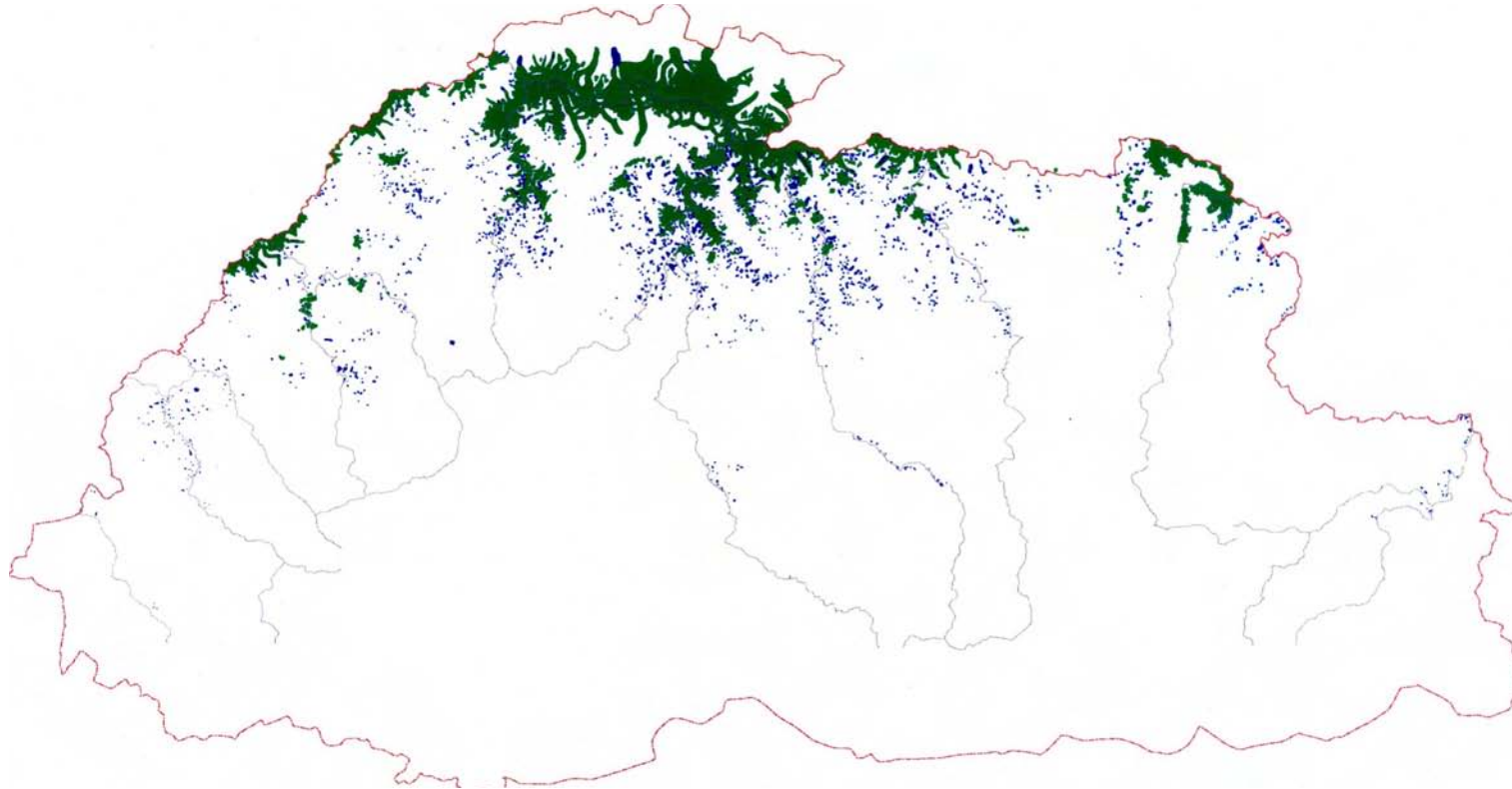


Population : 6,34,982

Religion : Mahayana Buddhism

Area : 47000 Km<sup>2</sup>

# Glaciers & Glacial lakes in Bhutan



## Types of glaciers and glacier lakes

- Glaciers : 1. Debris covered glacier (D-type)  
2. Debris free glacier (C-type)

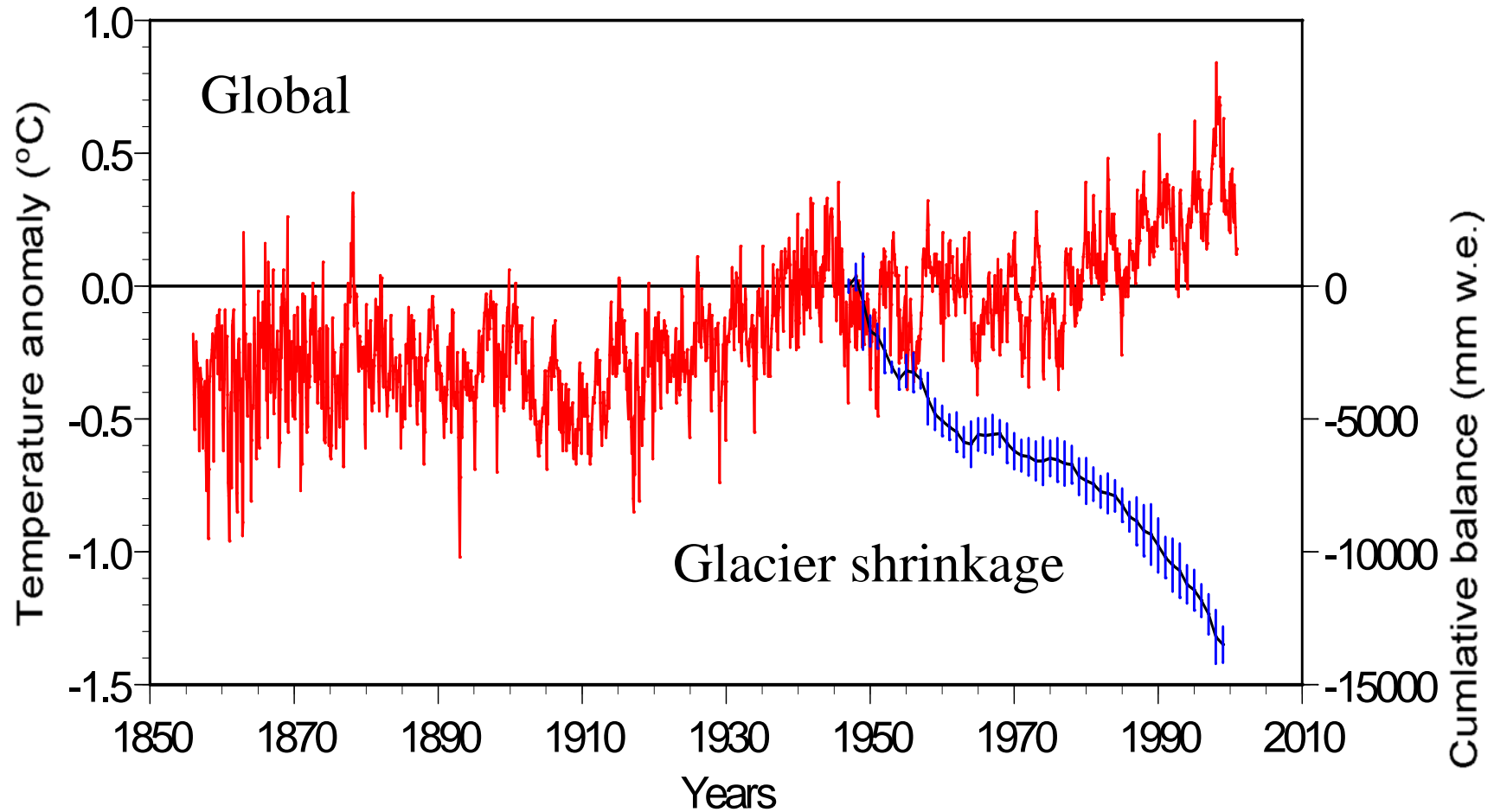
Glacial lakes: Moraine dam

Glaciers = 677

Glacial Lakes = 2674

Potentially dangerous lakes = 25

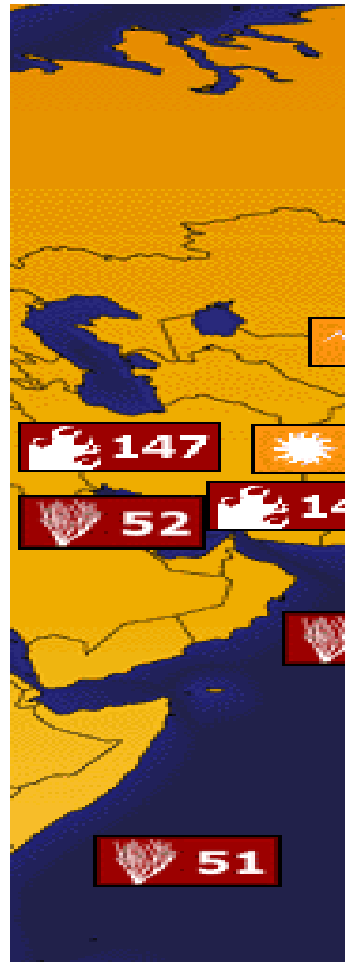
# Relation Between Temperature rise and Glacier Mass Balance



Im

arming in

IPCC 2001



Global warming event - M...

File Edit View Favorites >>

### Global warming fingerprint

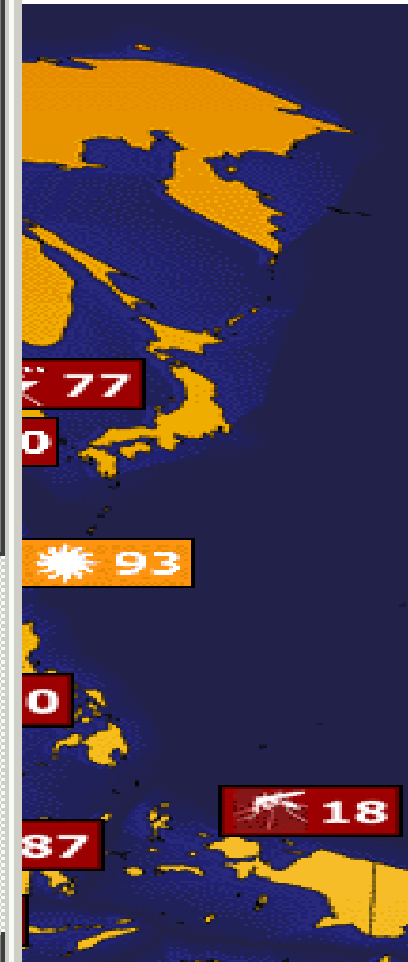
 **126** *Glaciers melting*

### Bhutan

As Himalayan glaciers melt glacial lakes are swelling and in danger of catastrophic flooding. Average glacial retreat in Bhutan is 100-130 feet (30-40 m) per year. Temperatures in the high Himalayas have risen 1.8°F (1° C) since the mid 1970s.

*Reference: ICIMOD, 2002. Inventory of Glaciers, Glacial Lakes, and Glacial Lake Outburst Floods, Monitoring and Early Warning Systems in the Hindu Kush-Himalayan Region - Bhutan, International Centre for Integrated Mountain Development (ICIMOD) ed.*

Internet





# Types of Glacier





# Change in Glacier

Oct. 1984



Oct. 1999



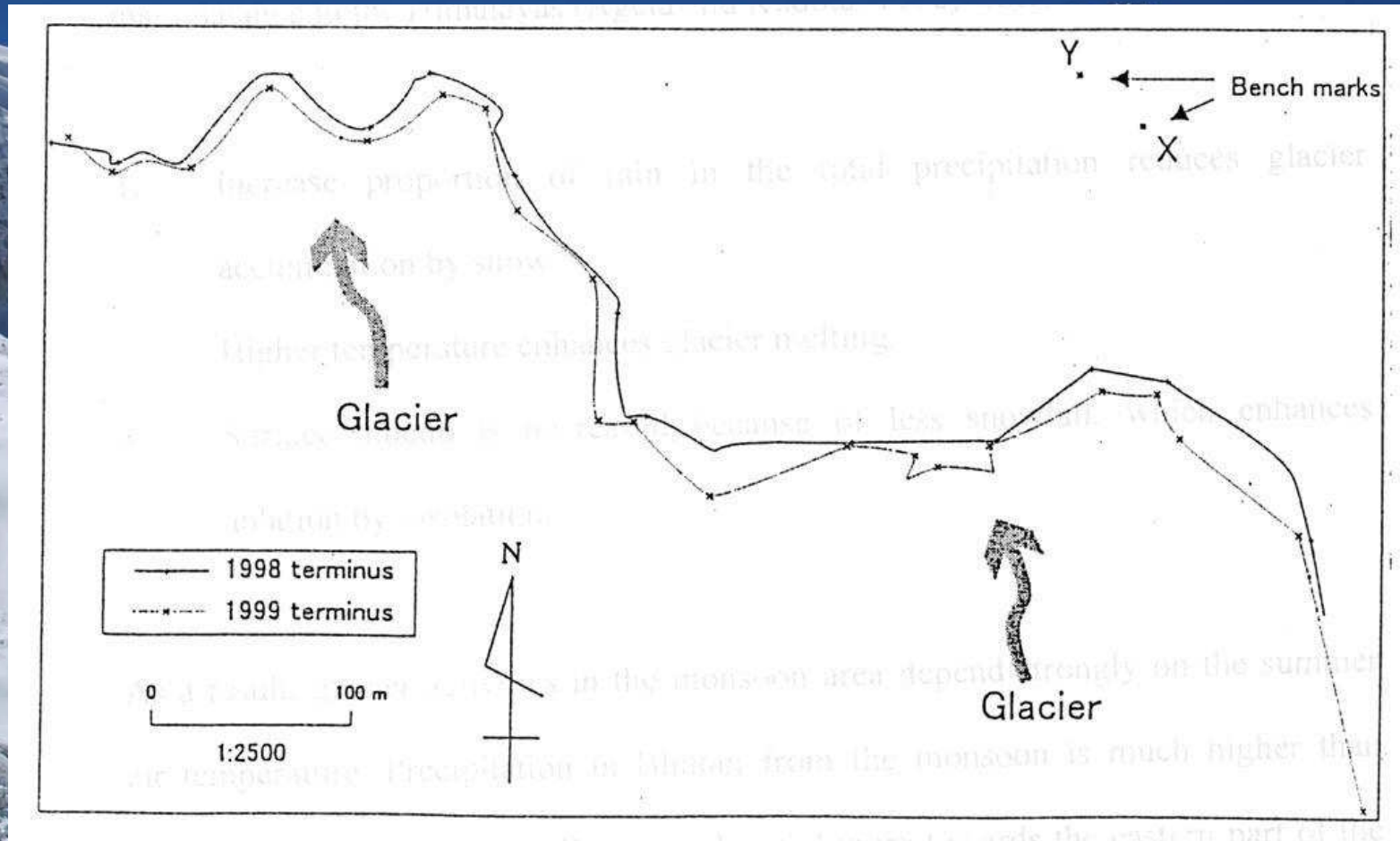


# Change in Glacier





# Jichu Dramo Glaciers



12 m Retreat rate with 2-3 m surface lowering (Naito et al 2000)

## Average fluctuation rates of glaciers in Nepal and Bhutan

For all types (retreating, stationary and advancing)

| Region | Duration<br>(years) | Horizontal retreat rate<br>(m/yr) | No. of<br>glaciers |
|--------|---------------------|-----------------------------------|--------------------|
| Nepal  | 34 (1958-92)        | <b>3.14</b>                       | 100                |
| Bhutan | 30 (1963-93)        | <b>6.27</b>                       | 103                |

For retreating glaciers only

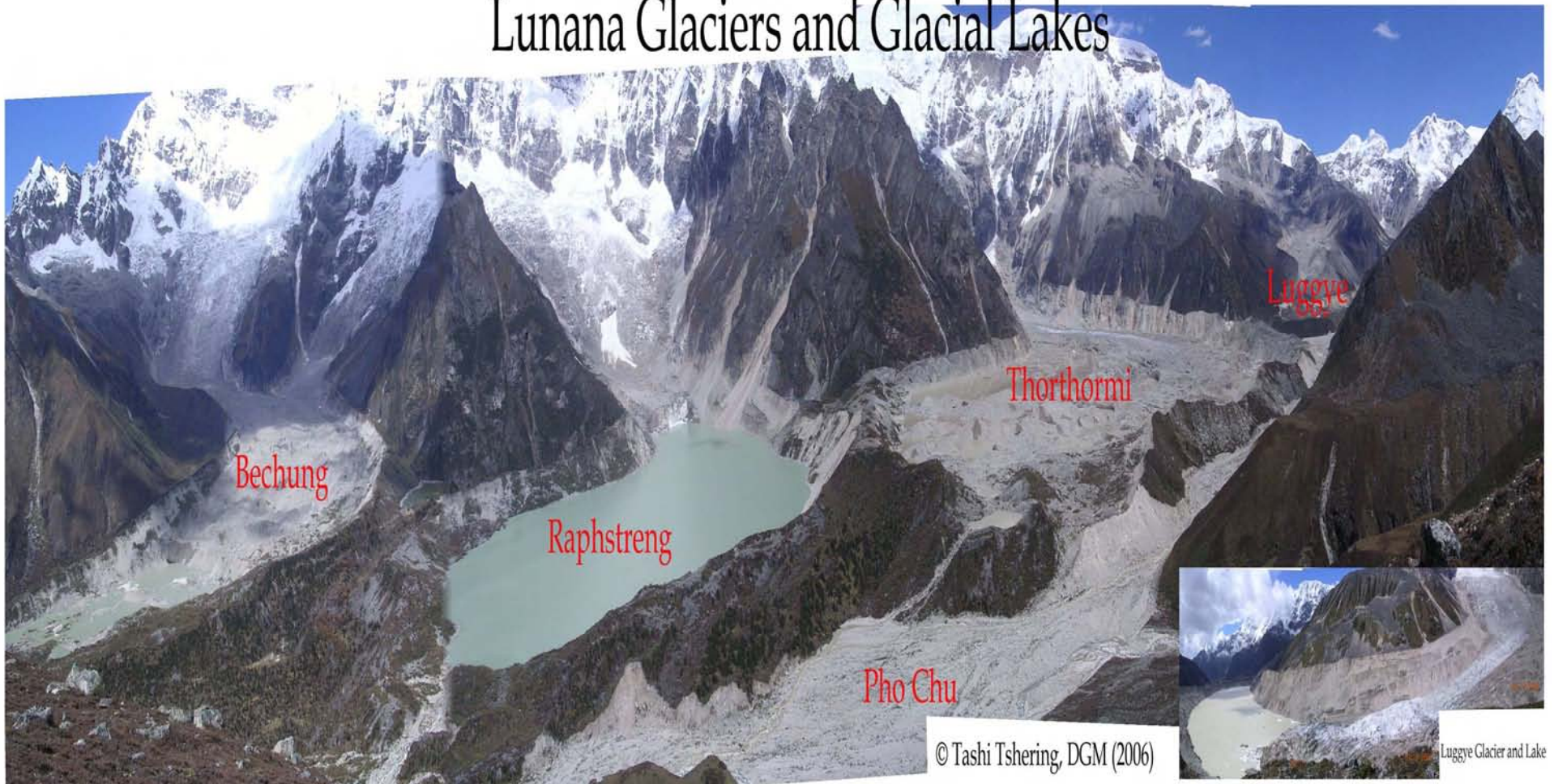
|        |              |             |    |
|--------|--------------|-------------|----|
| Nepal  | 34 (1958-92) | <b>6.61</b> | 58 |
| Bhutan | 30 (1963-93) | <b>7.36</b> | 86 |

Source : Karma et al 2003



# Debris covered glacier

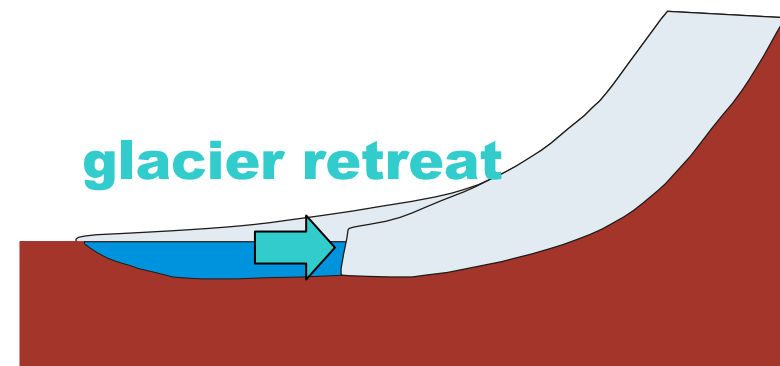
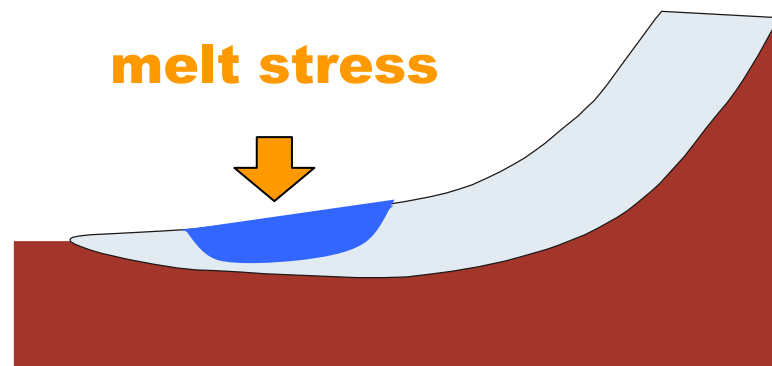
## Lunana Glaciers and Glacial Lakes





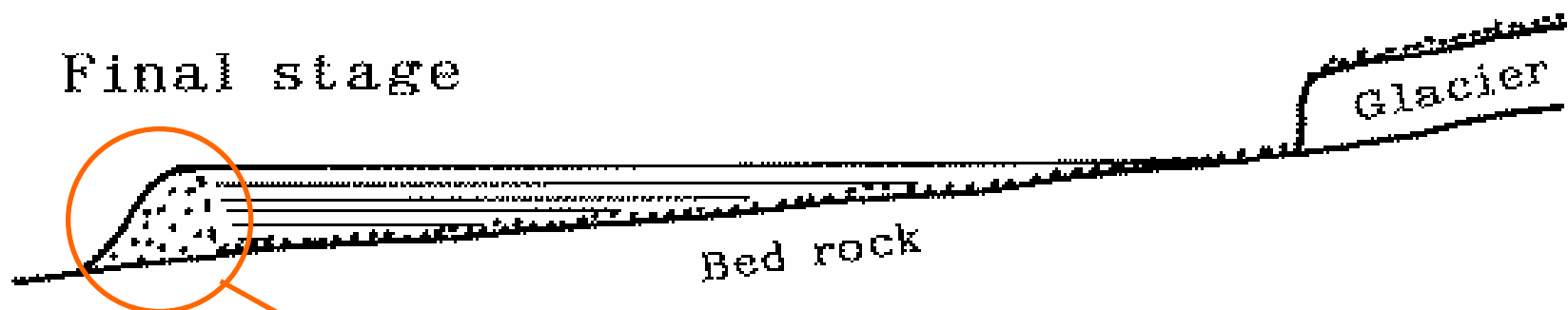
# Formation of Glacier Lake

- Melting process
  - as vertical thinning of glacier
- Glacier retreat
  - as horizontal expansion of lake



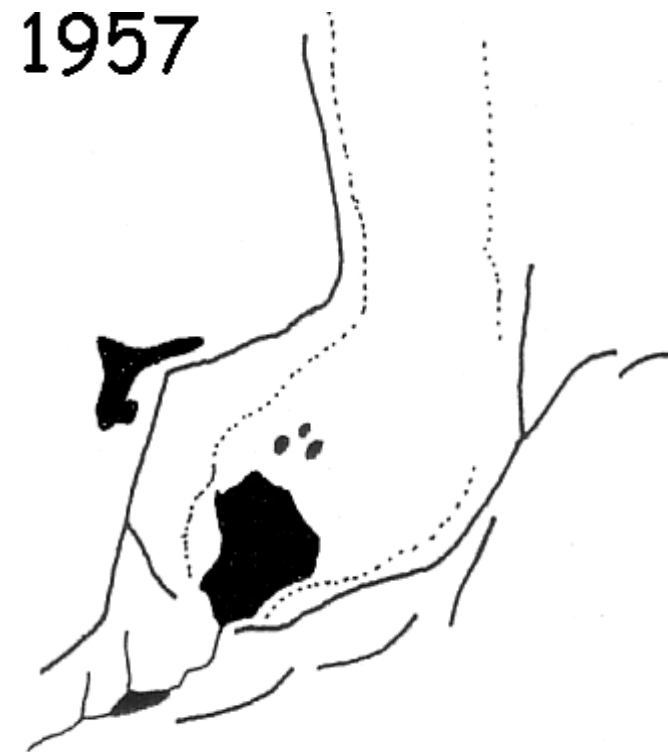
# Mechanism of Expansion

- Small ponds on the debris-covered area **Lugge II**
- Aggregated medium pond, expansion begin **Thorthormi**
- Large lake, rapid expansion continue **Lugge**
- Final stage, no more expansion **Raphsthreng**



GLOF depends on the moraine strength

# Expansion of Rapstreng Tso

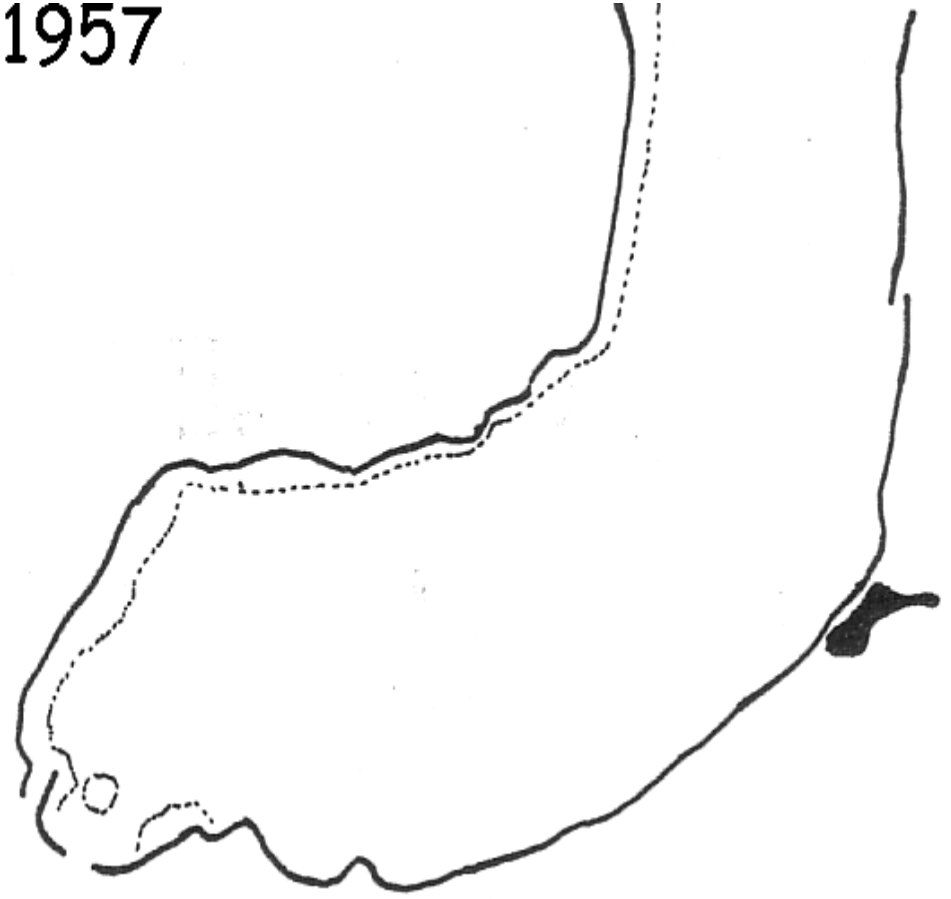




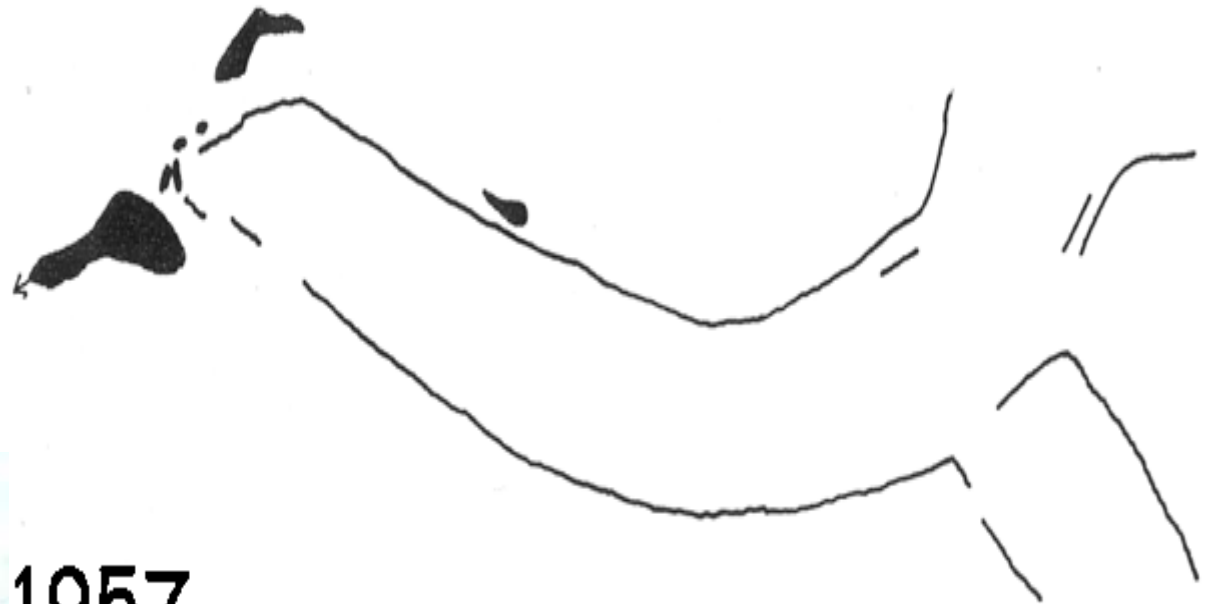
# Expansion of Thorthormi



1957



# Expansion of Lugge Tso



# Impact of Glacier retreat

From WFP Program Report in Nepal 2005

For 3 Countries (Nepal, India, China)

## 1. Fresh Water Regime

- Glacier retreat increase river levels
  - Flooding (IPCC 2001)
- Ice volume reduces with time
  - -- Reduction in run offs

### Example

- Reduction on Ganges river by two-third
  - 37 % India's irrigated land
  - 500 million people



# Impact of Glacier Retreat

## 2. Glacial Lake Outburst Flood

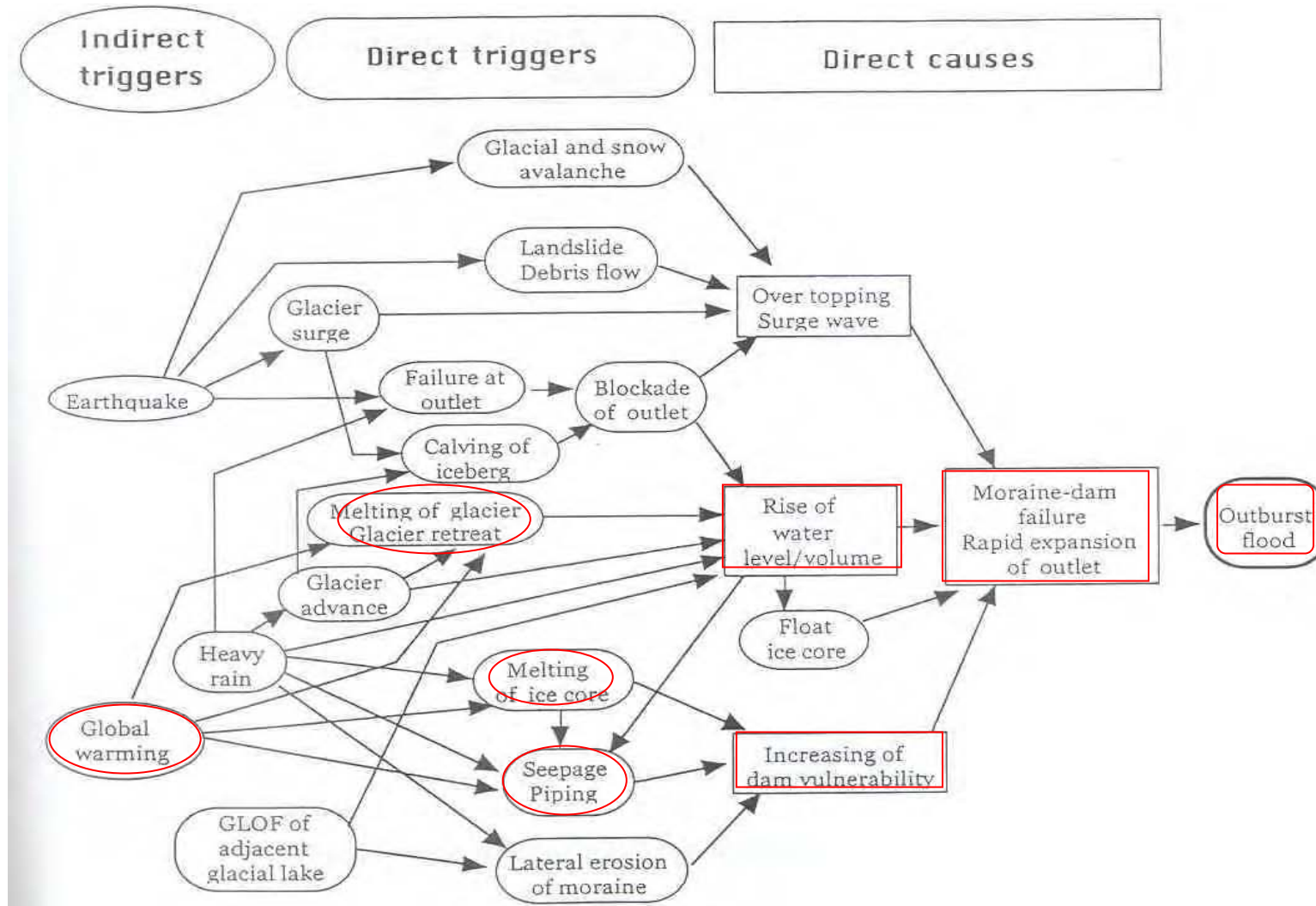
- Dig Tso in 1985 (Nepal)
- Zhangzangbo in 1964 & 1981 (China)
- Lugge Tso in 1994 (Bhutan)

# Impact of Glacier Retreat

## 3. National Economic Loss

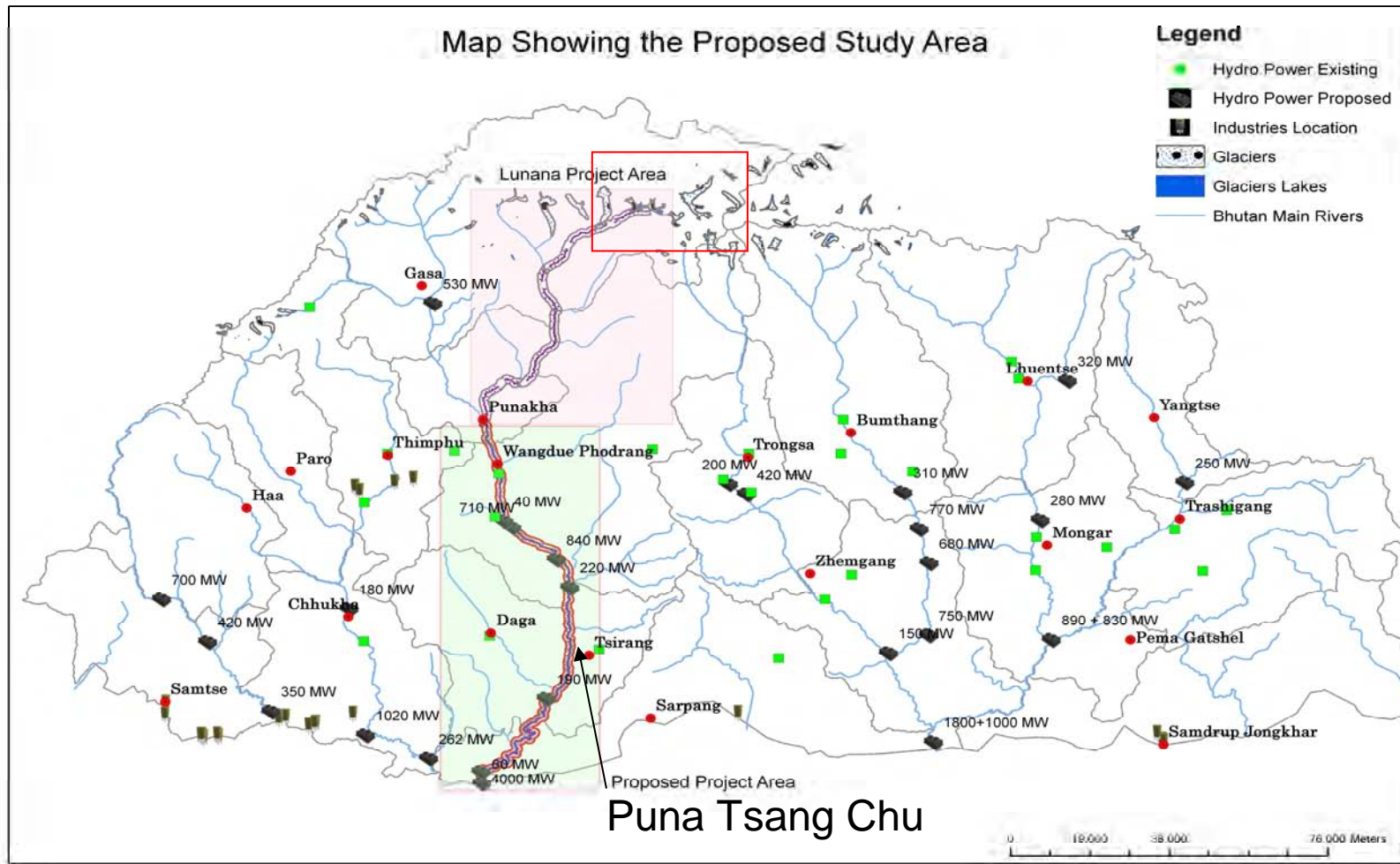
- Hydro Power
- Major Industries relying on water
- Water sensitive agriculture sector

# Possible triggers and causes for GLOF in the Himalayan mountains





# Risk in Bhutan



# What Can We do?

- Mitigate critical glacial lakes at the source
- Installation of Technical Early Warning System
- Hazard zonation for GLOF

To Save Lives and minimize damages to the property of the people

# Recent Projects

## DGM – NCAP Project

- Hazard zonation for GLOF along Puna Tsang Chu from Khuruthang to Lhamoizinkha

## DGM-UNDPGEF Project

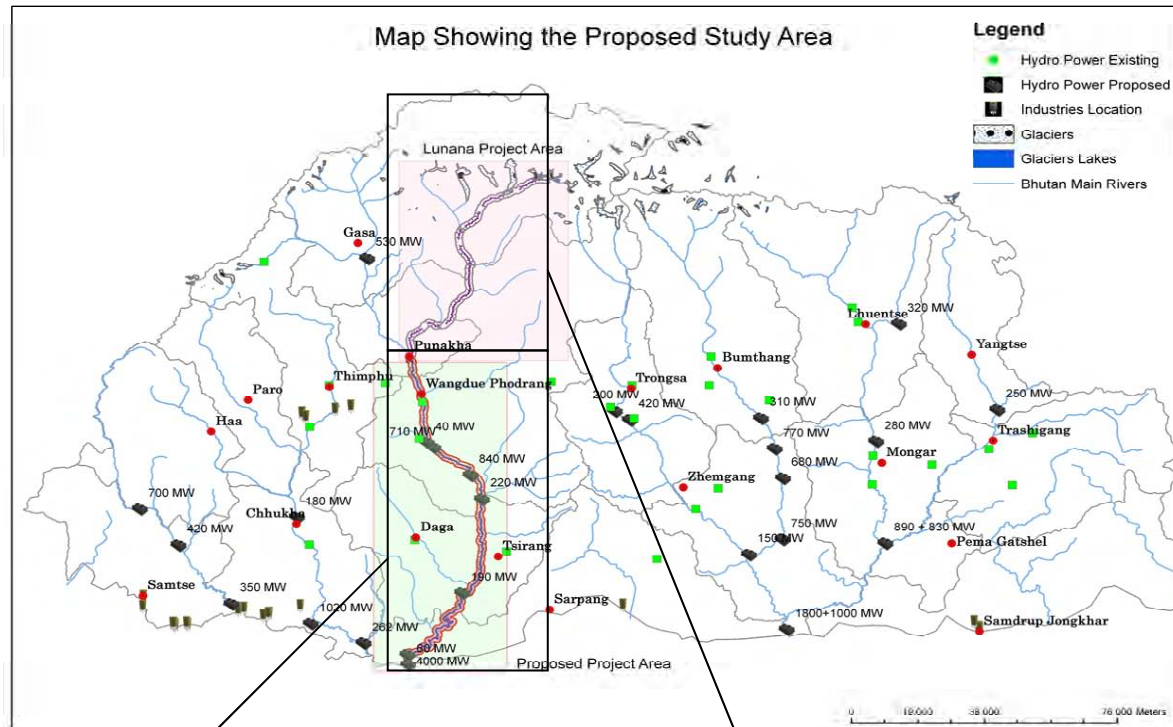
- Assessment for early warning system for GLOF

## DGM-UNDPGEF Project

- Lowering of thorthormi lake



# Project Area : DGM-NCAP project



DGM-NCAP Project Area

Hazard maps exist

- Hazard maps exist till Khuruthang
- Major developmental activities
- Settlements

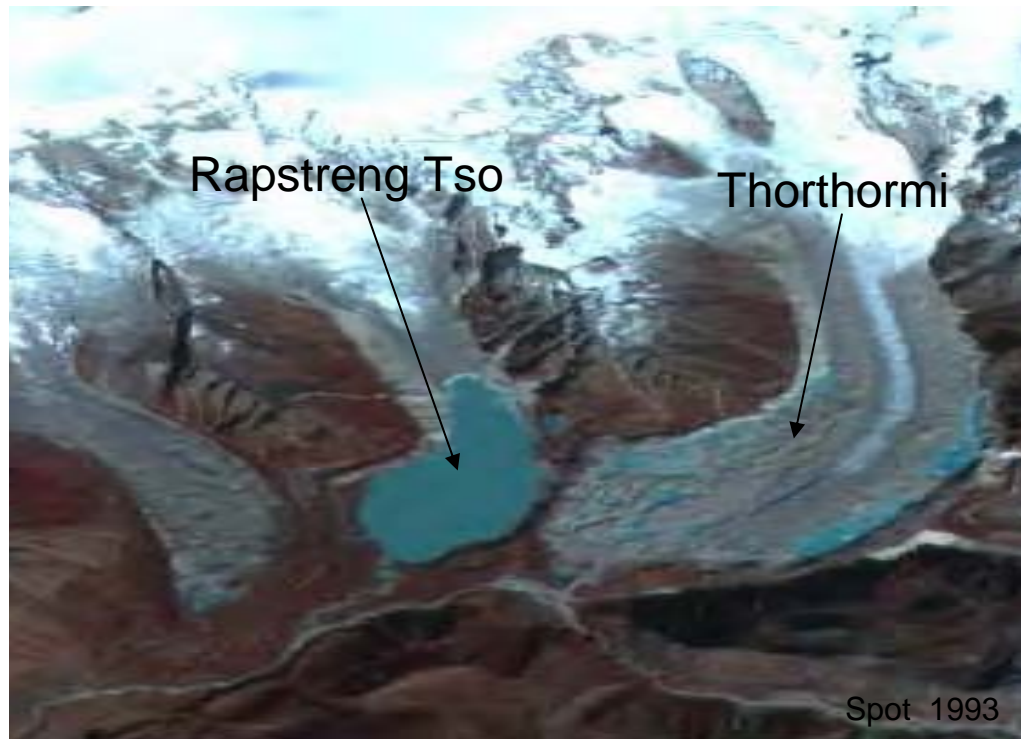
# Project Aims & Objective

- Base map for policy & decision makers and planners.
- To save lives & properties
- To render higher degree of safety to the local communities in the future.

**Hazard zonation map for GLOF of the  
area**

# Methodology

- Subjective Analysis
- Multi-criteria Evaluation



**BASIS :**

Worst Case Scenario

(Rapstreng + Thorthormi)

# What we did?

Delineated areas with different colour code representing different hazard level

|        |                    |
|--------|--------------------|
| RED    | High hazard zone   |
| YELLOW | Medium hazard zone |
| BLUE   | Low hazard zone    |



# Hazard & Vulnerability map



# Vulnerability Assessment

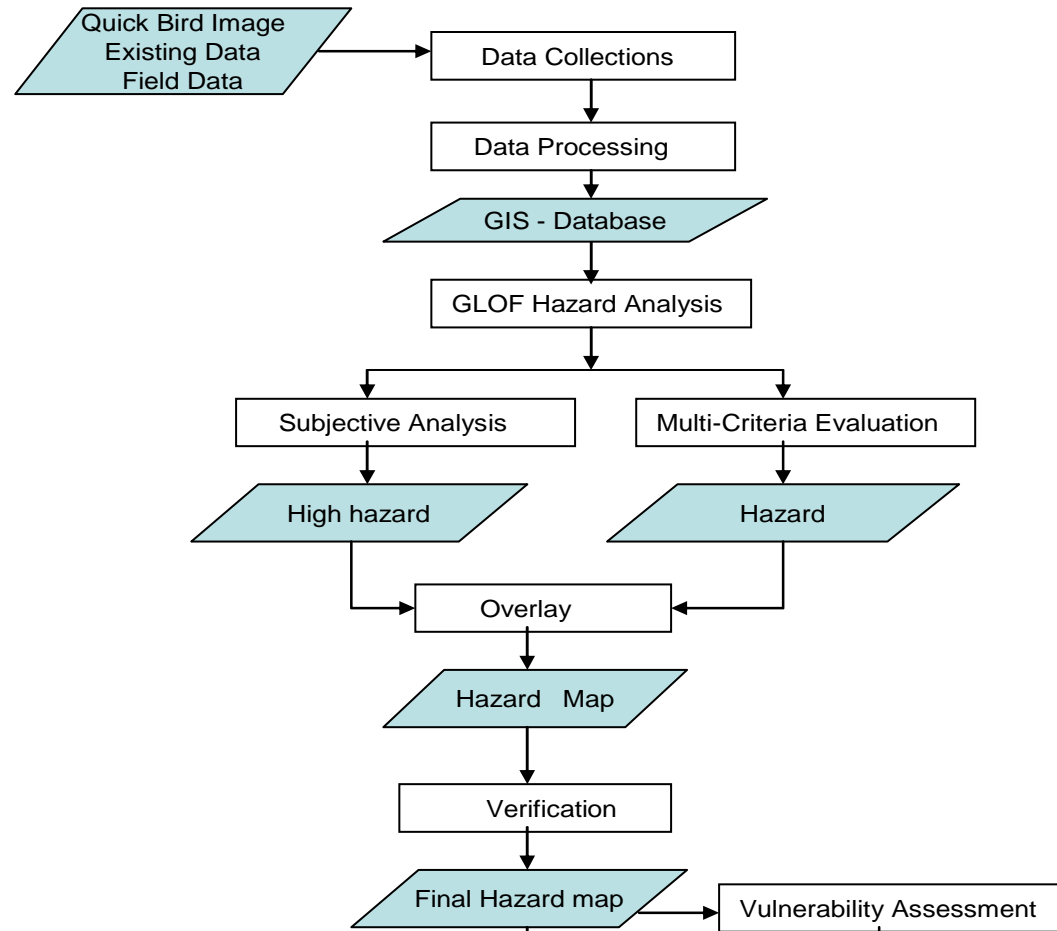
| Hazard Level | Map Color | No. of Buildings | No. of People | No. of Livestock | Historical Monuments | No. of Bridges | Road Length (Km) | Area (Km <sup>2</sup> ) |
|--------------|-----------|------------------|---------------|------------------|----------------------|----------------|------------------|-------------------------|
| High         | Red       | 46               | 136           | 06               | 04                   | 01             | 1.94             | 0.70                    |
| Medium       | Yellow    | 30               | 122           | 14               | 03                   | 00             | 2.51             | 0.93                    |
| Low          | Blue      | 44               | 96            | 17               | 02                   | 00             | 3.43             | 0.13                    |

| Hazard Level | Map Color | Cultivated Land (Km <sup>2</sup> ) | Arid Land (Barren, Open, Scrubs) (Km <sup>2</sup> ) | Forest Cover (Km <sup>2</sup> ) | Built Up Area (Km <sup>2</sup> ) |
|--------------|-----------|------------------------------------|---|---------------------------------|----------------------------------|
| High         | Red       | 0.02                               | 0.12  | 0.01                            | 0.06                             |
| Medium       | Yellow    | 0.02                               | 0.07  | 0.01                            | 0.03                             |
| Low          | Blue      | 0.59                               | 0.39  | 0.42                            | 0.28                             |

# Vulnerability Assessment

| Hazard Level | Map Color | No. of Buildings | No. of People | No. of Livestock | Historical Monuments | No. of Bridges | Road Length (Km) |
|--------------|-----------|------------------|---------------|------------------|----------------------|----------------|------------------|
| High         | Red       | 117              | 362           | 28               | 16                   | 01             | 5.22             |
| Medium       | Yellow    | 173              | 836           | 220              | 06                   | 06             | 8.64             |
| Low          | Blue      | 669              | 1781          | 1072             | 04                   | 00             | 39.92            |

# Project Frame Work





# THANK YOU & TASHI DELEK



Consequence of global  
warming