PROTECTING LIVELIHOODS AND ASSETS AT RISK FROM CLIMATE CHANGE INDUCED FLOODING IN GLACIAL RIVER BASINS OF NEPAL

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Scope of Work

1. Undertake flyover site observations and visual assessment reconnaissance survey for the design of GLOFs risk reduction measures for four glacial lakes;

2. Develop and produce a list of engineering alternatives for mitigation of GLOF risk in four glacial lakes catchments;

3. Estimate the total volume of water stored in the lakes by following the best possible approach;

4. Prepare topographic survey map using the images captured by drones and other secondary topographical datasets;

5. Develop a cost estimate based on locally acquired cost data and design drawings for hydraulic structures; including annual and periodic Operations and Management (O&M) considerations.

1. Thulagi Glacial Lake

Location: Manang District – Western Nepal

Basin: Marshyangdi basin, a sub basin of Gandaki

Coordinates: 28°31’47.67”N 84° 19’8.4”E

Elevation: 4044 m asl

Catchment area: 55.9 km^2

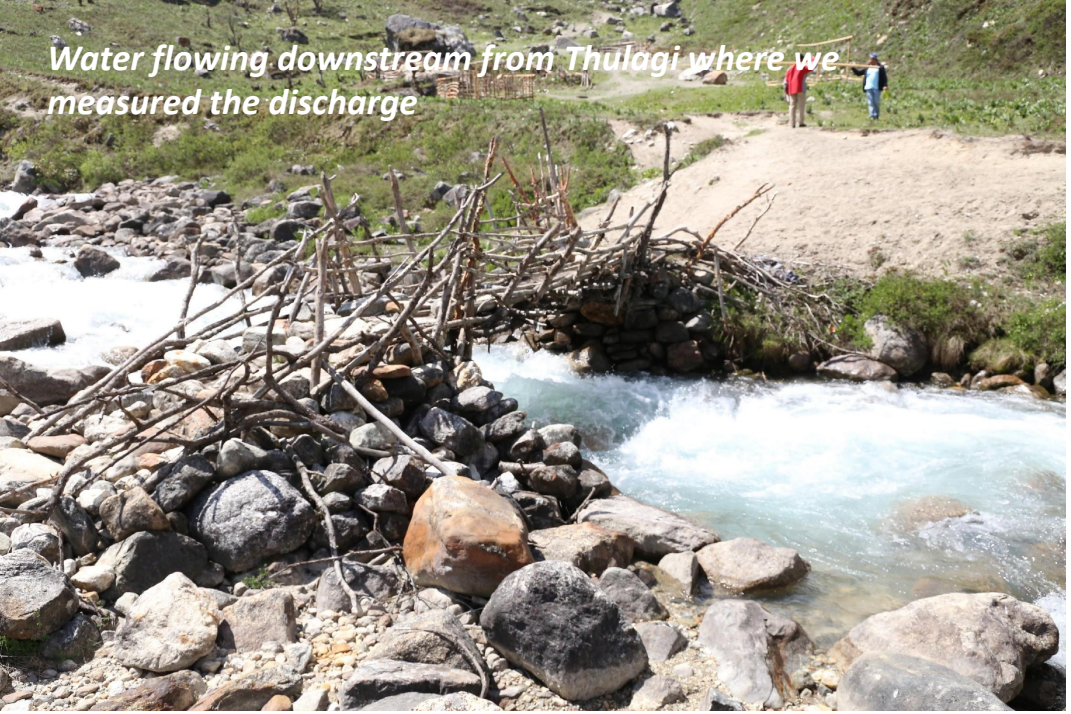
Glacial lake area: 0.9 km^2

Length: 2.44 km (2017)

***Max . Depth:** 76 m

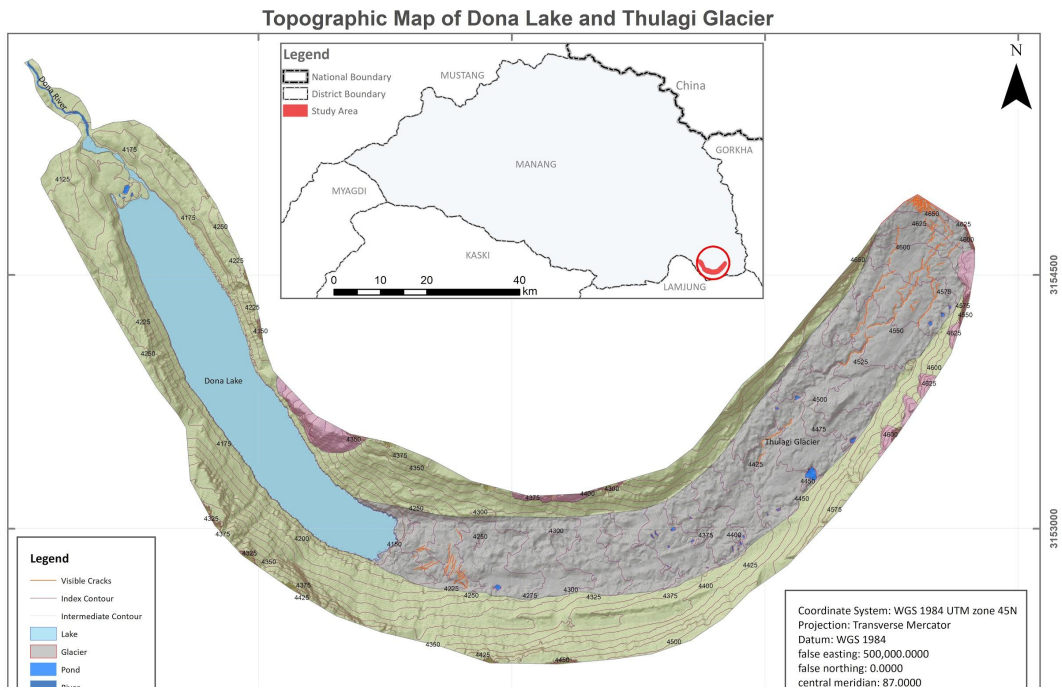
***Water volume:** $36*10^6$ m^3

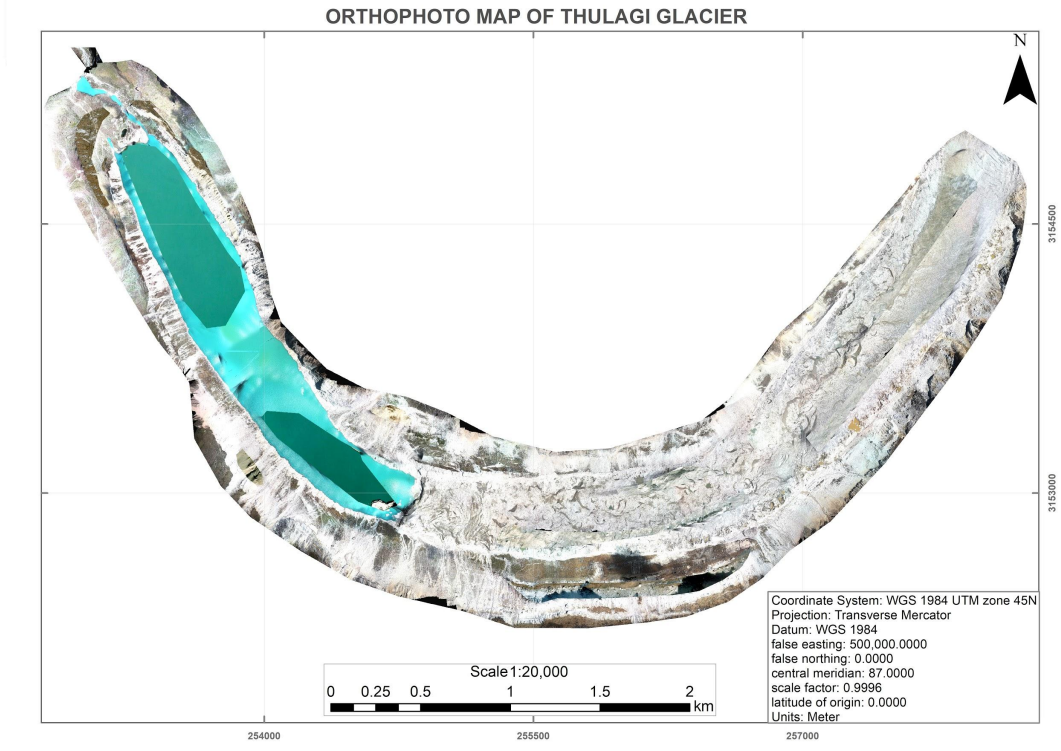
Moraine characteristics: Moraine dammed complex



Water flowing downstream from Thulagi where we measured the discharge

A small lake at the end moraine





Key Observations: Thulagi

- The lake has a outlet from the lateral end of the glacier terminus and the stream like formation is seen which at some distance in the downstream forms another ponding. There is sudden drop down through the outlet of that ponding.
- The proposed location for civil structure is comparatively stable because of the thick terminal moraine complex and an extension of the debris with a moderate slope towards the downstream, however, the piping effect and the splashing due to ice calving on the glacier terminus may create a problem for the instability in the future.
- End moraine of the glacier has a confined stream channel.
- Numerous crevasses on glacier terminus were observed.
- Through the rapid visual assessment and inspection through photographs no any seepage were observed from the glacial lake.
- Before any construction in and around the terminal moraine, the geophysical exploration should be conducted to find out the detailed characteristics of the moraine material such as void percentage and density of the material, saturation status, and level, bedrock level, etc.

2. Lower Barun Glacial lake

Location: Shankhuwashabha, Eastern Nepal

Basin: Arun, a sub basin of Koshi basin

Coordinates: 27.797007°N, 87.096101°E

Elevation: 4550 m asl

Catchment area: 55.22 km^2

Glacial lake area: 1.99 km^2 (2019)

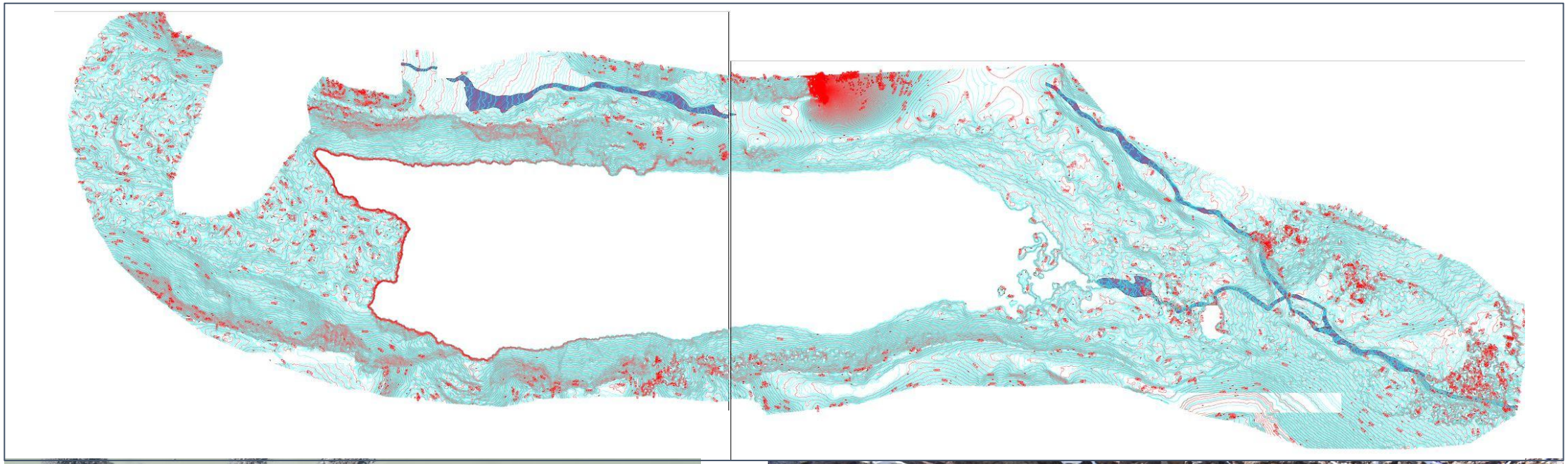
Length: 2.75 km (2019)

***Max . Depth:** 205 m

***Water volume:** 112.3*10^6 m^3

Moraine characteristics: Ice-cored end-moraine bounded by calving front of Lower Barun Glacier

- **from Haritashya et.al. 2018*
- *2019 data derived from Sentinel 2A images (Oct 15, 2019)*



A high resolution aerial image of Lower Barun end moraine captured by a drone mounted

Discharge Measurement by tracer method

Key Observations: Lower Barun

- There are two parts: the main lake and the pond in the terminus moraine. The main lake is situated in between the lateral moraines and the end moraine area has small poundage formation just upstream of the outlet area.

- The soil on the site comprises mainly colluvium till, talus, lateral moraine, terminal moraine, fluvial and lacustrine sediments, and colluvium. Many stream channels with two main channels were observed at the toe of the outer walls of the moraine dam.

- Numerous crevasses and ice calving front were observed in the glacier terminus and numerous ice blocks on lakes due to calving.

- The major geomorphic features of the area include talus deposits, landslides mainly rockfall, colluviums, and moraine soils.

- High possibility to breach upper section of left lateral moraine, if some event (such as, draining supra-glacial pond or GLOF's event) occur in the upper region in the Barun Glacier. This can impact on Lower Barun lake by addition of water with boulders and other materials that could generate wave displacement and can trigger for lake outburst of Lower Barun. So, it is crucial to design the civil structures to strengthen the left moraine section.

- Also, the right bank is susceptible to the risk of rockfall and rock slides due to the daylight condition of the discontinuity.

- Through the rapid visual assessment, it does not seem as seepage from the main lake, rather it was from the formation of the water channels through the main channel. *A detailed investigation is recommended to identify the source of seepage.*

3. Lumding Tsho Glacial Lake

Location: Solukhumbhu, Eastern Nepal

Basin: Dudhkoshi, a sub basin of Koshi basin

Coordinates: 27.779504°N, 86.613978°E

***Elevation:** 5141 m asl

Catchment area: 29.80 km^2

Glacial lake area: 1.37 km^2 (2019)

Length: 2.92 km (2019)

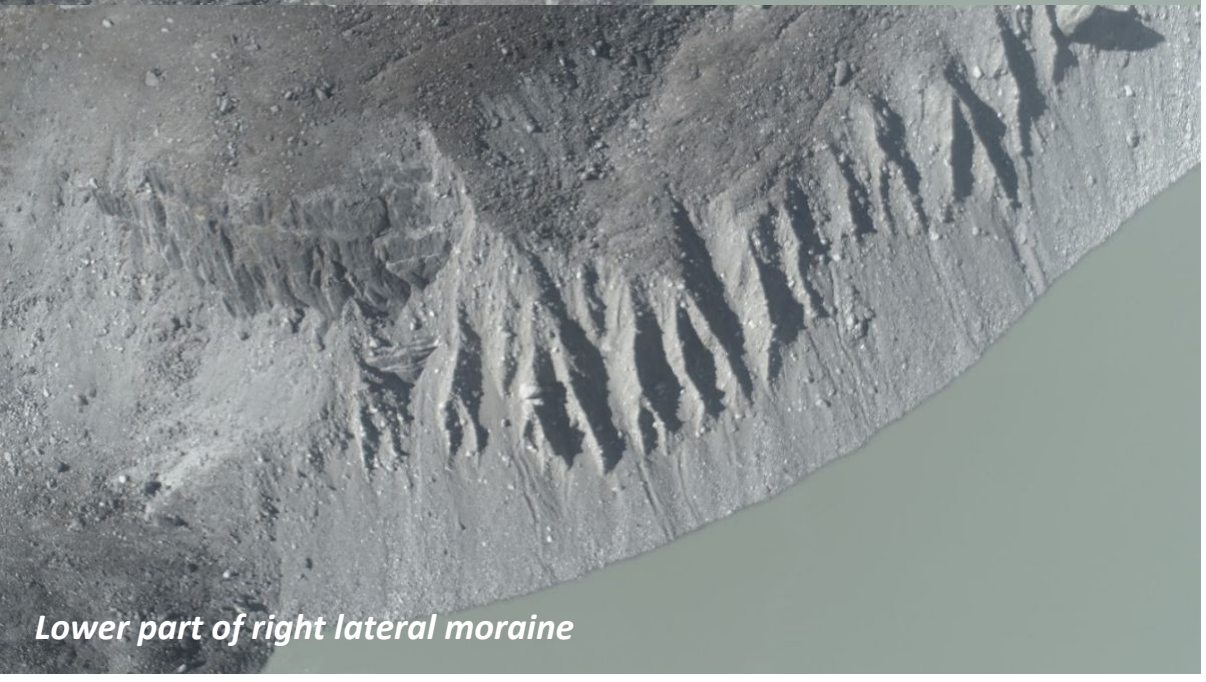
***Max . Depth:** 114 m

***Water volume:** 57.7 * 10^6 m^3

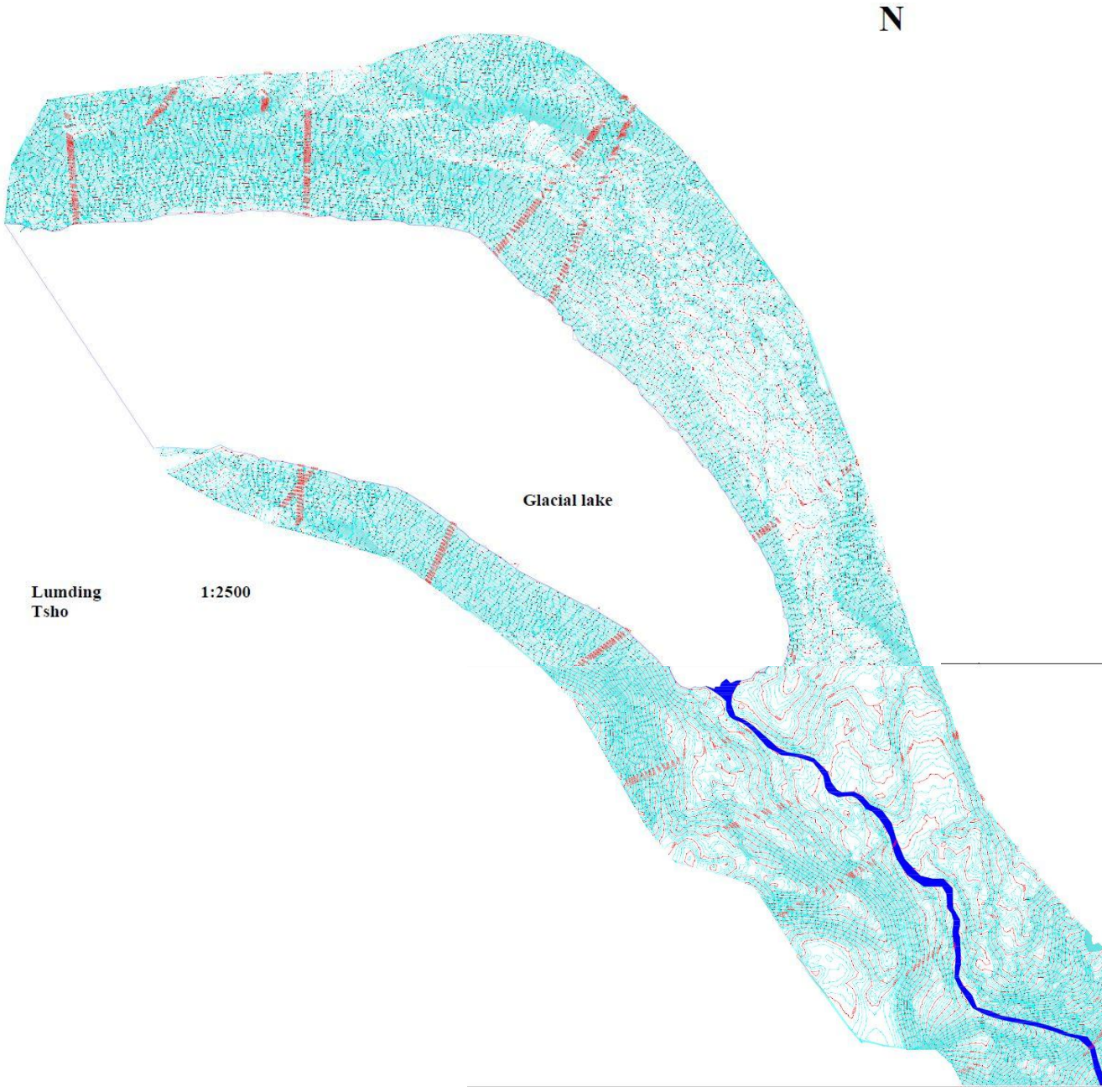
Moraine characteristics: relatively stable end-moraine, relatively gentle slope and fairly wide

- **from Rounce et al. 2016*
- *2019 data derived from Sentinel 2A images (Oct 15, 2019)*

Drone Imagery of end moraine



Lower part of right lateral moraine



Key Observations: Lumding Tsho

- An exposed bedrock with large waterfall ~1 km downstream of lake outlet (moraine crest) was observed.
- The water from the Lumding Tsho flows through a confined single channel to the downstream near the right moraine.
- End moraine was relatively gentle slope with fairly wide.
- Numerous crevasses and ice calving were observed in the glacier terminus.
- In a rapid visual assessment, the moraine seems to be comparatively stable with 5 - 10 m freeboard with no ice cliff exposed and the thermokarst than that of Lower Barun end moraine complex.
- The terminus and the lateral moraine ridges are composed of silty to sandy gravel and fine sands and silts made up of fluvial and lacustrine sediments.
- Detailed geophysical investigation needs to be carried out to investigate the moraine complex.
- The friction angle is between 25°- 30°, therefore the existing slope of the outlet downstream is less than the friction angle which implies that the area is safe from any slide in the present context.
- Before any construction in and around the terminal moraine, it is needed to conduct geophysical exploration to find out the detailed characteristics of the moraine material, for example, void percentage and density of the material, saturation status, and level, bedrock level, etc.

Drone Imagery of the End Moraine

End Moraine

4. Hongu2 / Chamlang North / Lake 464 Glacial lake

Also known as Chamlang North or Lake 464 or Hongu2

Location: Solukhumbhu, Eastern Nepal

Basin: Dudhkoshi, a sub basin of Koshi basin

Coordinates: 27.783756°N, 86.956724°E

Elevation: 5205 m asl

Catchment area: 6.42 km^2

Glacial lake area: 0.89 km^2 (2019)

Length: 2.29 km (2019)

***Avg . Depth:** 53.4 m (*calculated from Fujita et. al., 2013*)

***Water volume:** 29.1 $*10^6$ m^3 (*Calculated from Byers et. al., 2013*)

Moraine characteristics: Steep terminal moraine potential for a dynamic failure

- *2019 data derived from Sentinel 2A (Oct 15, 2019)*

Key Observations: Hongu2

- Based on aerial photo and visual assessment, no confined outlet and water channel were observed.
- Remains of past events ie. erosional features (scar on the outer slope of moraine) on the outslope of the moraine was observed. It may be due to overtopping lake water generated by certain avalanches in the past.
- The lake is in connection with the active hanging glacier front with numerous crevasses but there will be no further expansion of glacial lake as its sides are confined by relatively mountain slopes.
- Glacier meltwater from the hanging glacier front and other hanging glaciers drains to the lake
- Numerous ice packs were observed hanging to the Chamlang peak northern slopes.
- These ice packs were the vulnerable features which could directly fall into the lake, as avalanche with great impact with higher possibility to generate the wave displacement.
- The terminal has significant thickness and extension, however, the poorly graded sediments may create internal piping that may cause failure in the future.

Videos of the glacial lakes taken from the drone mounted on the helicopter

https://drive.google.com/drive/folders/10L-fXrqiz3Z6TvwoEmpELQxODY2-O2lN

Completed Works

March 15, 2019
Project Contract

May 21,2019
Submission of Inception Report

June 12,2019
Field Visit to Thulagi Lake

Nov. 19, 20, 21
Field Visit to Three Glacial lakes

Dec. 23rd, 2019 :
Submission of Progress Report.

Dec 29:2019:
Submission of Work Progress Slides

Remaining Works

Feb 25, 2020 :

Submission of Final draft report with

Engineering designs.

March 10,2020:

Final report submission including comments

THANK YOU