Chapter 10
The Glacial Lakes Studied in Bhutan

10.1 Previous Studies

The first study on the glaciers and glacial lakes in Bhutan was carried out by Augusto Gansser, a Swiss geologist, during his expedition to the Bhutan Himalayas in the 1960s and 1970s. During his expedition to Lunana in 1967 he identified a number of dangerous lakes which could flood in the lower valleys. He was of the opinion that the 1957 Punakha flood was due to an outburst from Taraina Tsho in western Lunana. He also identified a number of growing lakes and made sketch maps of the Lunana lakes. Gansser made small-scale maps of present day glaciers and glacial lakes of north and northwest Bhutan using LANDSAT images (Gansser 1983).

A preliminary aerial reconnaissance survey was carried out over the Lunana area (Raphstreng Tsho area) in September 1974 and August 1981 by a team of experts from the Geological Survey of India (GSI) to assess the probability of a flash flood by the bursting of the lake and the impact downstream along the Pho Chu Valley. The Royal Government of Bhutan (RGOB) initiated the survey when local people reported that the lake water level had risen to the extent of overflowing. The team was of the opinion that there was no immediate danger of outburst but recommended that a detailed ground survey be carried out.

In 1984 a joint expedition of the Geological Survey of Bhutan (GSB) and the GSI was carried out to study Lunana Lake (Raphstreng Tsho). Monitoring of inflow and outflow of the water discharge was carried out and a detailed map on a cale of 1:2,000 showing depth contours of the lake at 20-metre intervals was prepared. The team could stay for a duration of only 8 days. However the expedition resulted in a more detailed understanding of the relationship between the glacial lake and the glacier (GSI and GSB 1986). The team submitted a recommendation note for further detailed work on a continuing basis for a couple of years.

Lunana lake expedition (July to September 1986)

Following the recommendation of the 1984 expedition, in July 1986 a joint expedition team from GSB and GSI carried out detailed studies of Lunana Lake (now called Raphstreng Tsho). The team members were A.R. Sharma (Senior Geologist), GSI team leader; D.K.Ghosh (Junior Geologist), GSI; Phuntso

Norbu (Assistant Geologist), GSB; K.S. Ghalley and S. Kafley (Mineral Prospectors), GSB (GSI and GSB 1986).

The main objective of the expedition was to study, in detail, all aspects that had a direct bearing on a possible Lunana Lake outburst. The expedition team started trekking from Nika Chu Bridge on the 11 July 1986 and reached Lunana on 7 August 1986. The team could carry out detailed studies for a period of 36 days only, against the original planned schedule of 60 days, due to logistic constraints.

The detailed study carried out in the area comprised:

- hydrometry of the lake outlet stream,
- suspended sediment transport studies of the lake and outlet stream,
- ice flow studies of the glacier feeding the lake,
- geomorphological studies of the Thanza Valley, and
- recording of meteorological parameters of the area during the period of study.

From these studies the team came to a conclusion that there was no danger of a lake outburst in the near future but recommended periodical checks every two to three years due to the presence of ice cores in the moraine dams (GSI and GSB 1986).

Joint expedition team (1995)

After the flood on 7 October 1994, due to a breach of the Lugge Tsho resulting in loss of life and property, in 1995 the RGOB sent an Indo-Bhutanese team of experts (GSI and RGOB) to Lunana to carry out preliminary studies to identify the cause and effect of the flash flood in the Pho Chu. The team consisted of an engineering geologist, a structural geologist, a glaciologist, a surveyor from GOI, and other officials from RGOB. They recommended short-term and long-term mitigation measures (Dorji 1996a,b).

The short-term measures suggested were:

- that flow of the Pho Chu from Lugge and Tshopda Tsho area, be ensured by unloading the crown of the landslide located about 70 km downstream of Tshopda Tsho outlet and constructing gabion-toe walls on either bank of the Pho Chu,
- lower the outlet of Thorthormi by 10m in stages to reduce the hydrostatic pressure,
- restore the original section of the morainic barrier of Raphstreng Tsho washed away by the 1994 flood,
- lower the level of Raphstreng by 20m to reduce the volume by 38% and hydrostatic pressure from 68,152 kN to 51,799 kN, and
- draining should be carried out in stages as sudden draw down can lead to slope failure.

It was suggested that the short-term mitigation measures mentioned above would not withstand catastrophic events like earthquakes, so it would be necessary to implement the long-term measure of constructing check dams, dykes, and other structures to reduce the energy of the flood, thus reducing damage downstream. It was also suggested that fast-growing shrubs, grass, and trees having soil holding capacity be planted to stabilise the slopes. It was recommended that seismic and meteorological stations be set up and that regular monitoring of the lakes be carried out.

Expedition to Roduphu glacial lake (1996)

This expedition was undertaken based on the report that there is a lake which could burst and cause flooding downstream. The expedition was funded by the National Environment Commission and coordinated by the Ministry of Home Affairs. Team members were from the Division of Geology and Mines and the Division of Roads of the Survey of Bhutan and National Environment Commission (National Environmental Commission 1996).

The expedition team discovered three small lakes in the headwaters of the Roduphu Chu, a major tributary of the Mo Chu. A desk study of the 1989 SPOT image showed that Roduphu Tsho III, situated at about 4,750 masl, was 300m long and 175m wide with no visible surface outlet. In July–August 1996 the expedition discovered evidence that the lake had been drained recently by 1.55m. The team also reported that during retreat of the Roduphu Glacier a number of small lakes were being formed (Roduphu Tsho I) which could become sizeable lakes in a decade or so. These lakes have outlets that flow over and under the morainic deposit. Although these lakes do not pose immediate danger, periodic physical monitoring was recommended.

All the detailed investigations carried out in Bhutan were in the eastern Lunana region (Raphstreng Tsho area). A number of expeditions went to study this lake due to its earlier history (not recorded in writing) and the recent GLOF of 1994. The other glacial lakes studied (preliminary studies) are the glacial lakes in the headwaters of the Chamkhar Chu and the Paro Chu.

Japan–Bhutan joint research programme (1998)

Nagoya University, Tokyo Metropolitan University, and the GSB undertook a joint research programme in 1998. The objective was to prepare an updated inventory of major glacial lakes located at the headwaters of Bhutan and to produce an assessment of the dangers of GLOF, including ranking of the vulnerability of glacial lakes by a combined study on the variation of glacial lakes and the surrounding glacial area (Ageta and Iwata 1999).

The following studies/observations were carried out.

- Eighteen glacial lakes named by the Division of Geology and Mines and 12 other glacial lakes were observed.
- Water temperature (vertical profile) and lake depth of GLP9 (Raphstreng Tsho) were surveyed.
- Three automatic weather stations were established in Lunana region to measure air temperature, precipitation, and maximum snow depth.
- Jichu Dramo Glacier in the southern part was surveyed for mapping by terrestrial photogrammetry.
- Geomorphological observations of glaciated zones and areas surrounding glacial lakes were made, and dating samples were collected from moraines and sediments for reconstruction of palaeo-environmental changes.
- The relationship between glacier variation and glacial lake change was checked for recent years from a glaciological point of view.
- Water samples for stable isotope measurements and data of ground temperature distribution were collected for an analysis to be made of the hydro-climatological environment in high mountainous areas where glacial lakes are distributed.

Based on the above studies, observations, and data collection, an updated glacial lake inventory and risk assessment of moraine dam failure of the glacial lakes in Bhutan were presented in the report on 'Assessment of Glacier Lake Outburst Flood in Bhutan' (Ageta and Iwata 1999).

10.2 Glacial Lakes Studied

The lakes of Bhutan that have been studied are described below. The extent of studies carried out on these lakes was not the same. Among the lakes studied, Raphstreng Tsho drew the attention of most of the investigators.

Raphstreng Tsho (eastern Lunana)

After identification of a number of dangerous lakes by Gansser's expedition in 1967 to Lunana area, Lunana Lake (now called Raphstreng Tsho) drew the attention of RGOB and other researchers. As explained in previous sections, in 1974 and 1981 aerial reconnaissance surveys were carried out over Lunana area (Raphstreng Tsho) by the Geological Survey of India. In 1984 a joint expedition was made by the GSB and the GSI to carry out a ground survey. A detailed map on a scale of 1:2,000 showing depth contours of Lunana Lake at contour intervals of 20m was also prepared during this expedition.

For more detailed studies, in 1986, a joint expedition team of the GSB and the GSI was sent to Lunana Lake again. The following major studies were carried out by the expedition team.

Hydrometry of the lake outlet stream

To measure the water discharge from the lake outlet a bridge approximately at right angles to the stream was used. Water discharge was calculated using the area velocity method. A current meter was used as the velocity measuring instrument. The area was calculated from the cross section prepared by measuring the depth of the stream at every 1m along the width of the stream. Velocity measurements were taken every 1m along the width of the stream by lowering the current meter from the bridge and submerging the propeller at least 30 cm below the surface of the water.

Using the water discharge values obtained by the above method and the corresponding gauge level records (recorded every hour between 0800 and 1700 h), a rating curve was drawn to estimate the water discharge values. From the 10 hourly discharge values, the average rate of discharge in $m^3 s^{-1}$ was calculated for each day. The total water volume for a period of 31 days from 12 August 1986 was $21.27 \times 10^6 m^3$. Average discharge per day was $0.68 \times 10^6 m^3$.

Suspended sediment transport studies of the lake and outlet stream

To study the suspended sediment transport of inflow and outflow of the lake, water samples were taken from the lake reservoir and outlet of the lake. These samples were filtered through ashless filter paper no. 42 and weighed. Then they were ignited using the ashing procedure and the residue weighed to calculate the silt content in tonnes. A total of 46 samples was collected. It was found that for the period of 26 days between 13 August and 7 September 1986 (i) the average rate of sediment discharge was 125.82 t day^{-1}, (ii) the average rate of sediment input was 154.08 t day^{-1}, and (iii) the average rate of siltation was 28.26 t day^{-1}.

Ice flow studies of the glacier feeding the lake

This study was carried out to see whether there is any glacier surge tendency, or the ice flow is restricted only to glacier surface movement. Two stakes were fixed across the width of the glacier about 350m upstream of the glacier snout. The observations were taken for a period of 16 days from 20 August. By this method it was observed that the average horizontal movement varied from 8.5 cm day^{-1} to 17.5 cm day^{-1}. Although the data are insufficient to come to a definite conclusion, up to an average horizontal movement of 17.5 cm day^{-1} definitely does not indicate any surging tendency of the glacier.

In Lunana, four glaciers were recognised with well-defined boundaries and separate from each other (numbered as Glaciers I, II, III, and IV). The elevation of the snout of these glaciers ranges from 4,150 masl to 4,200 masl. Glaciers III and IV, now known as Thorthormi Glacier and Lugge Glacier respectively, are at a higher level than Lunana Glacier (Glacier II) which is now called Raphstreng Tsho Glacier. The snout of Glacier III is wider than the snout of other glaciers in Lunana and no lakes were observed in 1986. It was assumed that in future, as the glacier melts, it would deposit more frontal moraine thereby increasing the width between Lunana Lake and Glacier III. The only unstable portion in Lunana Lake was the left flank of the snout, from where morainic debris was sliding into the lake during summer months. Two dead ice patches were observed, on the eastern and western margins of the lake at the existing water level and more was expected within the morainic deposit in the same areas.

Geomorphological studies of Thanza Valley

Geomorphological studies were also carried out in Thanza Valley, but not in detail. It was believed that the whole of Thanza Valley was a glaciated valley with its outlet at Tshojo Village. This is evidenced by the number of end and lateral moraine deposits left by the fast retreating glaciers in the valley. This geomorphology later was changed by fluvioglacial process giving rise to sharp and wide gullies. The flood plain (1.5 km long and 0.75 km wide) between Tenchey and Tsojo represents an old glacial lake. The widest part of the valley lies beyond Tsojo between Lhedi and Rholo, after which the Pho Chu enters deep gorges.

To record the meteorological parameters of the area during the period of study, a small meteorological station was set up to measure daily precipitation, maximum and minimum temperature, variation in daily temperature, and relative humidity (Table 10.1). The instrument used was a maximum–minimum, dry and wet bulb thermometer of IMD specification.

Table 10.1: Variation in daily temperature, precipitation, and relative humidity (observation time 08:00 h, observation period 8 August to 13 September 1986)

Meteorological parameters	August	September
Maximum daily temperature		
Highest maximum	23° C on 8 August	17° C on 3 September
Lowest maximum	10° C on 11 August	9.5° C on 12 September
Minimum daily temperature		
Highest minimum	7° C for 6 days	17° C on 02 September
Lowest minimum	3° C on 19 August	4° C on 11 September
Daily precipitation		
Total rainfall	75.5 mm for 24 days	60.8 mm for 12 days
Maximum rainfall	20.6 mm on 19 August	10.2 mm on 10 September
Rain free days	4 days	Nil
Humidity		
Highest	98% on 11 August	97% on 12 September
Lowest	80% for 8 days	80% for 4 days
Average	85.5%	86%

The studies carried out by the 1986 expedition revealed the safety of the morainic barrier surrounding the lake with no signs of possible breaching in the near future. However, it was recommended that periodical checks every two or three years would be required in view of the presence of ice core in these moraines which on melting is likely to effect geomorphological changes by way of subsidence.

In 1996 RGOB sent an Indo-Bhutan team of experts in to carry out immediate short-term mitigation measures for Raphstreng Tsho. More detailed studies were taken up simultaneously. During this period, in addition to the collection of hydrometeorological data, a topographical map of Raphstreng Tsho outlet area was prepared on a scale of 1:2,000 with contour intervals of 2.5m. From this contour map cross sections and longitudinal sections at required locations were prepared.

Other investigations

Three samples were taken from different locations and subjected to the following tests: mechanical analysis, Atterberg limits, specific gravity, and chemical analysis. The Atterberg limits test indicated that all three samples showed non-plastic characteristics. Based on grain size analysis and the Atterberg limits test, two of the soil samples fell into the GP-GM group and one fell into the GP group of the Indian Standard of Soil Classification System. Specific gravity of the soil samples (passing 4.75 mm sieve) varied from 2.69 to 2.70. Using the data collected in the field, stability analysis was carried out and it was found that, if the reservoir level of the lake is at 4,347.6 masl in elevation, it is critical. If the level is at 4,344.7 masl in elevation then the slope is just stable, so it was recommended that the lake level be lowered to 4,344.7 masl in elevation (WAPCOS 1997).

In 1998 the Japan–Bhutan research team carried out field observation along the 'Snowman Trek' route, in the north and northwestern part of Bhutan (Ageta and Iwata 1999). The focus of the field observation was to observe water temperature distribution of Raphstreng Tsho, to ascertain the thermal condition of the lake, and to find out if there is seepage from Thorthormi Glacier into Raphstreng Tsho.

Measurements were carried out on 6 October 1998 using a water temperature profiler, ABT-1 (ALEC Electronics Company Ltd) on a rubber boat. The instrument can measure water temperature at an interval of 1-metre depths with an accuracy of 0.1°C. Measurement sites were located using a theodolite. The vertical profile of water temperature was measured at 18 sites (11 sites located in the middle of the lake and seven on the left edge of the lake along the morainic ridge separating Thorthormi Glacier). The bathymetric map of the 1986 expedition team was used. Observations showed that the surface temperature of the lake was in the range of 10-15°C and decreased with depth to 4°C at around 20m depth at all the sites. The water temperature profile of the seven sites on the left side of the lake along the ridge separating Thorthormi Glacier did not indicate any sign of seepage from Thorthormi Glacier into Raphstreng Tsho. The result of the study indicated two possibilities: (i) the water temperature of the seepage is almost the same as that of the lake water of Raphstreng, or (ii) due to the small amount of seepage water, the seepage water mixed with the lake water and the seepage water did not make a distinctive layer in Raphstreng Tsho.

The other observations made by the joint research team were climatic. Three automatic weather stations were established in Lunana region (Thanza, upper part of Jichu Dramo Glacier, near the terminus of Jichu Dramo Glacier) to measure air temperature, precipitation, and maximum snow depth. The results of these observations have not yet been published.

The research team produced a check list for risk assessment of moranic dam failure and/or lake burst and a data sheet for a glacial lake inventory in the Bhutan Himalayas. From these data sheets, risk assessment of moraine dam failure and/or lake burst and a glacial lake inventory of 30 lakes observed were produced in the report 'Assessment of Glacier Lake Outburst flood in Bhutan (Ageta and Iwata 1999).

In 1999 the Austro–Bhutan expedition team carried out integrated geophysical, hydrological, and geological investigations in the Lunana area with special emphasis on Raphstreng Tsho and Thorthormi Tsho (Häusler et al. 2000).

The materials/equipment used were:

- Digital Indian Remote Sensing Satellite Series 1D (IRS-1D) image data, panchromatic with ground resolution of 5.8m, of 3 January 1999,
- topographic maps of the area of the scale 1:50,000 (Survey of India),
- WTW-LF318 instrument to measure conductivity (equipment manufactured by Wissenschaftlich Technische Wersatten (WTW) company,
- WTW-pH320 to measure pH,
- WTW-pH330 with a SenTixORP redox to measure redox potential,
- stepped frequency ultra wideband sub-surface imaging radar (SUSI), frequency range 1 MHz –8 GHz, was used for subsurface radar investigation,
- seismograph (24 channel ABEM terraloc Mark III) for seismic refraction and reflection investigation,
- resistivity meter with multi-core cable system, and
- theodolite.

From the digital IRS-1D image and topographic map of the area, using ERDAS/IMAGINE software, satellite image maps on scales of 1:25,000 and 1:5,000 were produced for use as base maps to monitor glacier decay and for field survey. A 3-D digital elevation model was prepared to help in the interpretation of geology and geomorphology.

The Raphstreng terminal moraine is made up of three terminal moraine ridges of different ages. The youngest is in contact with the lake, while the outermost ridge is the oldest. The left lateral moraine of Raphstreng is affected by mass movement, especially along the Raphstreng–Thorthormi moraine segment. As this process continues, the possibility of a dam break is high from Thorthormi Lake, which in the future will develop into a large lake.

During the hydrological investigation water samples were collected for analysis of stable and unstable isotopes, tritium, and unstable isotope for dating of water. In addition water temperature, electrical conductivity, pH, and redox potential were measured. Tracer experiments were also conducted using natrium nitrate and urainine to find the source of seepage.

For the sub-surface radar investigation, the band width selected was 100 MHz leading to a depth resolution of about 1.5m depending on the actual soil conditions. The centre frequency selected was 150 MHz in conjunction with 512 frequency lines. The antennas selected were a modified dipole, 60cm apart and horizontally oriented at 90° with respect to profile line (Häusler et al. 2000).

For the seismic investigation a geophone spacing of 20m was selected. For refraction investigation the shot point distance was 120m, whereas for the reflection survey for the RT9901 spread it was 5m and for the TT9902 it was 10m. Recording time for all records (refraction and reflection) was 500 ms, giving a sampling interval of 0.5 ms. The charge was placed at an average depth of 0.7m. For processing of refraction data, software developed by Joanneum Research using the 'generalised reciprocal method' by

D. Plamer was used. The software used for processing reflection data was FOCUS/DISCO (Paradigm Geophysical) on a UNIX based workstation.

For electrical resistivity investigation, a one channel multi-core cable system with 56 stainless steel electrodes was used for acquisition of field data. For processing the data, RES2DIVN software was used. The purpose of this investigation was to delineate ice cores and groundwater flows in the moraines.

From the analysis of the data collected, risk potential was estimated and presented in the report of the Raphstreng Tsho Outburst Flood Mitigatory Project (Häuslar et al. 2000)

Roduphu glacial lake

In July 1996 an expedition was undertaken to Roduphu Sinchhe Glacial Lake based on the report that there was the possibility of a lake burst in that region which could cause a flood hazard downstream (National Environmental Commission 1996).

The team physically verified the lake (Roduphu Tsho III). It is situated at an elevation of 4,750 masl. In the SPOT image of 1989 the lake measured 300m long and 175m wide. During field verification it was found to be a shallow greenish-blue lake about 120m long and 80m wide. It has been observed that the left lateral moraine on which the lake is situated has been affected by progressive landslides and due to this the lake has been recently drained by 1.55m as evidenced by the fresh water mark along the periphery of the lake. The outlet formed is 10m wide and still has active landslides on both sides of the slope. It is envisaged that this lake will decrease in size and become a tiny lake or even a stream only as its basin is continuously eroded by landslides.

It was also observed that within the retreating Roduphu Glacier several small lakes were being formed (Roduphu Tsho I) which could form into sizeable lake in a decade or so. These lakes have an outlet that flows over and under the morainic deposit. Although these lakes do not pose immediate danger, periodic physical monitoring was recommended in the brief report on the Expedition to Roduphu and Sinchhe Glacial Lakes (July–August 1996).

Tshokar Tsho glacial lake

Tshokar Tsho, one of the main lakes feeding the Chamkhar Chu, falls under the Choekor Gewog in Bumthang Dzongkhag. Two expedition teams (one to Tshokar and the other to Upe Tsho) were fielded in April–May 1999 based on the information that Tshokar Tsho and Upe Tsho could burst (Karma and Tamang 1999).

Tshokar Tsho is located at an altitude of 4235 masl and measures about 1.2 km x 0.5 km. This lake serves as a reservoir for the lakes which lie above it (eight lakes were observed which ultimately drain into Tshokar Tsho). A small slide occurred 650m upstream from the inlet to Tshokar Tsho in the summer of 1998, measuring 300m in length with a maximum base width of 200m. This may have been caused by increased discharge from the upper lakes combined with the breaching of Gangri Tsho I, which lies above it. The whole channel length was eroded and bedrock exposed. The inlet of the lake was filled up with sand, logs, gravels, and big boulders (Karma and Tamang 1999). The outlet is 60m wide and the outflow is smooth. The whole area is well vegetated with cypress trees, silver fir, and thick bushes. No seepage was observed along the entire slope of the outlet. Water discharge measurements at the outlet and the inlet were recorded for a period of 15 days.

During the expedition, apart from the Tshokar Tsho, eight other lakes were reported where Gangri Tsho I (Table 10.2) with a hanging glacier (Gangri Glacier) about 300m above the lake had breached as evidenced by the V-shaped channel in the terminal moraine (in 1998, according to yak herders).

Upe Tsho glacial lake (1999)

The investigation of Upe Tsho was taken up, for the reasons mentioned in the previous section, in April–May 1999. The area around Upe Tsho was geologically mapped. The area studied lies within the latitudes 27°46'30" and 27°49'15" N and longitude 90°37'15" and 90°38'45" E in topographic map sheet No. 79 I/9.

Table 10.2: Summary of the lakes			
Name of Lake	Altitude (masl)	Dimension (km)	Remarks
Gangri Tsho I	4,820	0.20 x 0.15	Has a hanging glacier; breached in 1998
Gangri Tsho II	4,900	0.65 x 0.15	Detached glacier; thin moraine layer at the outlet over rock exposure; monitoring required
Gangri Tsho III	4,680	0.90 x 0.50	Surrounded by rock all around (stable)
Tsangdumroe Tsho	4,360	0.25 x 0.15	No danger at present
Zangdopelri Tsho I	4,440	0.46 x 0.35	-do-
Zangdopelri Tsho II	4,380	0.27 x 0.19	-do-
Gangbi Tsho	5,050	0.33 x 0.20	-do-
Tshonak Tsho	4,400	0.75 x 0.33	-do-
Tshokar Tsho	4,235	1.20 x 0.58	Largest lake; all the above lakes drain into it

The general lithology of the area consists of gneiss and schists of the Thimphu Formation with intrusions of pegmatites and lucogranites. The general trend of the formation is north–east dipping northwesterly. There are 11 major glacial lakes reported in the Upe region (Table 10.3) and the region is divided into Lower Upe and Upper Upe.

Table 10.3: Summary of the lakes in the Upe region							
Lake name	Altitude (masl)	Dimension (km)	Depth Appr. (m)	Inflow (l s^{-1})	Outflow (l s^{-1})	Outlet slope (°)	Remarks
Lower Upe Tsho	4,480	1.5 x 0.45	12.0	6.3	41.8	43	Largest lake; wide joints along outlet slope which could cause slope failure
Upper Upe Tsho	4,560	0.75 x 0.25	9.0	3.7	3.0	12	No direct outlet; water comes on surface after 40m downstream
UUT 1	4,780	0.25 x 0.25	6.0	none	2.2	34	Clear outlet; stable
UUT 2	4,760	0.18 x 0.08	5.5	none	1.5	42	Steep cliff at outlet; stable
LUT 1	4,920	0.25 x 0.08	6.5	none	2.5	34	Stable
LUT 2	4,680	0.18 x 0.05	4.8	none	3.3	34	Flows directly into Lower Upe Tsho; stable
Tsho Chum Tsho	4,560	1.25 x 0.20	6.0	7.0	8.3		Clear, wide outlet; stable
1. TST 1	4,600	0.28 x 0.20	5.0	2.4	2.6	11	Wide outlet opening into U-shaped valley
2. TST 2	4,640	0.15 x 0.13	4.5	none	2.4	7	Stable
1. DS1	4,640	0.38 x 0.12	7.0	4.0	4.6	34	Stable
2. DS 2	4,760	0.25 x 0.08	5.0	none	4.0	28	Stable

Lower Upe Tsho, the largest lake in the Upe region lies at an altitude of 4,480 masl and measures 1.5 km x 0.4 km at the headwaters of the Chamkhar Chu. From field observations, Lower Upe Tsho is a moraine-dammed lake with no attached glaciers (Kuenza and Gyenden 1999).

Lower Upe Tsho is charged by many small streams, a lake code-named LUT2, and Upper Upe Tsho. The outflow of Lower Upe Tsho was recorded as 41.8 l s^{-1}. Lower Upe Tsho has a well defined outlet but the probable danger is that there are large joints at the outlet, with joint spacing of 2m, which could, in the future, due to freezing and thawing, lead to failure of the dam.

Upper Upe Tsho lies at an altitude of 4,560 masl. It is in the form of a crater lake surrounded on all sides by steep, barren mountains. The lake is fed by two other lakes located northeast and northwest, code-named UUT 1 and UUT2, and has an outflow of 3 l s^{-1}. Upper Upe Tsho has the capacity to accumulate large amounts of water and if it bursts it can trigger the flooding of Lower Upe Tsho (Karma and Gyenden 1999).

Chubda Tsho glacial lake

An expedition was made to Churapokto Tsho GLC5 (now called Chubda Tsho as the lake lies in the place called Chubda) in the headwaters of the Chamkhar Chu to carry out a field check as it was shown to be a large lake attached to a glacier in the inventory 'Glaciers and Glacial Lakes in Bhutan' (Geological Survey of Bhutan 1999).

The expedition team prepared a topographical map of the Chubda Tsho area at the scale of 1:5,000 using the tape and tripod compass method and took daily water discharge measurements for 14 days at the outlet (Kuenza 1999).

Chubda Tsho is a supraglacial lake within the Chubda Glacier. It lies at an altitude of 4762 masl and is about 3.4 km long and 0.3 km wide. The water is muddy with fresh ice cliffs in the middle of the lake. Some of the smaller supraglacial lakes have clear water, unlike the main lake. Several number seepage points were noticed with a major seepage point observed on the right side of the outlet at the base of the slope of the end moraine. The discharge from this seepage was as large as that from the outlet stream. This glacial lake poses a major hazard to the lower valleys of Bumthang and therefore needs to be monitored constantly. Mitigation measures may be taken after carrying out a detailed study of the lake and the glacier associated with it.

Other lakes

The other lakes reported are described below.

Thana Tsho I located at an altitude of 4,670 masl is a clear bluish water coloured lake, having dimensions of about 500 x 300m. The lake does not have an open outlet but flow comes out as seepage beneath the boulders. The lake is fed by the melt water from the snow and ice existing on Markhang La about 150m above the lake.

Thana Tsho II lies in the northeast of Thana Tsho I at an altitude of about 5,000 masl and measures 500m x 100m. The associated glacier, Thana Glacier named after Thana Gang (mountain), is 400m away from the lake located at an altitude of 5,080 masl (hanging glacier). The width of the glacier snout is about 400m with an average thickness of 20m. The visible length of the snowfield is about 1 km. The lake is fed by two small streams flowing from either side of the glacier. The water from the stream smells of sulphur and even the boulders are coated with yellowish stains (Kuenza 1999).

Ngangami Tsho lies at an altitude of 4,730 masl. It was once a large lake. Breaching of the lake in the past is evidenced by the V-shaped cutting in the end moraine. The exact year of the burst is unknown, but according to local people it occurred in the 1950s. Inside the terminal moraine large sand bars with horizontal laminations were observed. The melt water from the glacier, which is 1.5 km away from the lake, flows into the lake. The outflow from the lake comes out as seepage through the end moraine.

Churabuk Tsho lies at an altitude of 4,900 masl with clear water. It is 500m long and about 200m wide. The lake is fed by Chubda Glacier located 600–700m away from the lake.

Pamey Tsho also has clear water and lies at an altitude of 4,780 masl, south of Monla Karchung La. It is in the form of a cirque lake measuring about 400m x 250m. It has a clear outlet, but most of the outflow comes out as seepage through the end moraine.