

Chapter 3

Hydro-Meteorology

3.1 GENERAL CHARACTERISTICS

There are six main river basins mostly flowing from north to south in Bhutan. The river basins listed from west to east are as follow:

- Amo Chu (Torsa) Basin,
- Wang Chu Basin,
- Puna Tshang Chu (Sankosh River) Basin,
- Manas River Basin,
- Nyere Ama Chu Basin, and
- Northern Basin, comprising rivers flowing from Bhutan towards Tibet (China).

General descriptions of these river basins are given below.

The Amo Chu basin

The Amo Chu or Torsa River originates in Tibet with three main tributaries, the Tangka Chu, the Khangphu Chu, and the Tromo Chu, all flowing south. The main branch of the Tromo Chu starts from the west of Phari Dzong and flows south to join the Bhutan–Tibet border at Trakarpo. This tributary then flows roughly along the border for about 0.5 km (aerial distance). It then joins with the Amo Chu at Yatung, flows eastwards and enters Bhutan 9 km southeast of Yatung. It drains about 16,000 sq.km of Tibetan territory before entering Bhutan, where it flows southeast for about 170 km and then enters the Indian flood plains of West Bengal near Phuntsholing (a border town of Bhutan). Its catchment area is about 19,650 sq.km.

This river basin is not associated with any glaciers in Bhutan. A total of 71 lakes has been identified in this river basin and the cumulative area occupied by these lakes is 1.8 sq.km (1960s map of Amo Chu area).

The Wang Chu basin

The Wang Chu Basin lies entirely within Bhutan and consists of three rivers:

- Thim Chu,
- Pa Chu, and
- Ha Chu.

The Thim Chu River flows south for about 70 km and then it becomes the Wang Chu. The Ha Chu (the western tributary) originates from south of the Masang Kyugdu Range. The Ha Chu flows southeast for about 70 km, where it joins with the Wang Chu. Its catchment area is 323 sq.km. The Pa Chu has tributaries, namely, the Chomolhari Chu, the Halun Chu, and the Thangochang Chu. The Halun Chu and the Thangochang Chu (Pa Chu Main) originate from the Chomolhari and Kang Phu Glaciers respectively. The Pa Chu flows southeast for about 80 km and joins with the Wang Chu. Its catchment area is 1,049 sq.km. The Wang Chu exits from Bhutan at Lamchey between Phuntsholing and Kalikhola. As it enters into India, it is known as Raidak.

In the Wang Chu Basin there are 36 glaciers and 217 lakes. Most of the lakes are small in size and only a few are associated with glaciers. At present these lakes do not pose any danger of glacial lake outburst floods (GLOFs).

The Puna Tshang Chu basin (Sankosh)

The Puna Tshang Chu Basin has been formed by the joining of the Mo Chu and Pho Chu Rivers. The Mo Chu originates from the northeastern slope of Chomolhari and the Pho Chu from the western slope of Kula Gangri (Lunana area). The Puna Tshang Chu is the longest river (250 km) in Bhutan. The Mo Chu Basin has boundaries of the Kangphu–Nilela–Nigilela Range in the west and the Tsenda Gang–Ganglakarchung Range in the east. The Mo Chu has two main branches, one is the western branch and the other is the eastern branch. The western branch consists of the Lingshi Chu and the Chhijethang Chu originating from Takaphu and Gangchhen Ta Glaciers respectively. The eastern branch comprises the Mo Chu Kangu, the Zamtognangi Chu, the Taksikhai Chu, and the Rodhophugi Chu. The Lingshi Chu flows northeastward and joins the Chhijethang Chu flowing south to become the Gasa Chu. The Gasa Chu then flows eastwards to join the Mo Chu near Gasa. The Mo Chu Kangu has two major tributaries, the Sinchhe Chu and the Sagchhagi Chu with its source mainly from Gangchhen Ta Glacier. Two tributaries of the Zamtognangi Chu, are the Kamgigi Chu and the Sachhuphugi originating from Masagang and Khebechen Glaciers respectively. The Taksikhai Chu flows from Phungdoh Glacier and glaciers around Droma La. The Roduphugi Chu flows from Roduphu Glacier. The Puna Tsang Chu enters India near Kalikhola and is then known as the Sankosh.

The Mo Chu Basin comprises 118 glaciers and 380 lakes. The largest glacier is Mo_gr 96 covering an area of 13.22 sq.km. The total area covered by the glaciers in the basin is 169 sq.km with an estimated ice reserve of 11.34 km³.

The Pho Chu, the eastern branch of the Puna Tsang Chu, originates from the numerous glaciers in the Lunana Valley. The Pho Chu has two branches, a western and an eastern branch. Sources of the western branch are from the Tarina Glaciers and sources of the eastern branch are from the Lunana Glaciers. The Pho Chu flows through deep gorges and rugged terrain and joins the Mo Chu immediately south of Punakha Dzong to form Puna Tsang Chu.

A total of 154 glaciers and 549 lakes exists in the Pho Chu Basin. Among them 71 glaciers feed the western branch of the Pho Chu. The largest is the Wachey Glacier (Pho_gr 71), with a length of 20.12 km and covering an area of 38.52 sq.km. The largest glacier in the Pho Chu Basin, Tshoju Glacier (Pho_gr 79), is located in the eastern branch of the Pho Chu. The total area covered by the glaciers in the basin is 334.36 sq.km with estimated ice reserve of 32.27 km³.

The Manas River basin

The Manas River is formed by the joining of two rivers of similar catchment area, the Mangde Chu and the Dangme Chu. The Mangde Chu is the westernmost branch of the Manas River—it starts from the Gangkar Punsum Mountain and has a length of 140 km. In the northern region the Mangde Chu has three major tributaries, out of which two have their origins from glaciers and snow covered terrain. The eastern branch of the Mangde Chu originates from a large valley glacier (Mangd_gr 117) immediately

south of Kang Ri Summit (7,239 masl). The Mangde Chu western branch emerges from the glaciers south of Yaksagang and southwest of Kang Ri Summit. Further south of the Mangde Chu western branch is the Tampe Chu, another tributary of the Mangde Chu, draining southeast. The Mangde Chu flows south below the spur of Trongsa Dzong and is joined by the Chamkhar Chu a few kilometres north of Panbang in Zemgang Dzongkhag.

The Mangde Chu Basin has 140 glaciers and 521 lakes. The glaciers in the region occupy an area of 146.56 sq.km with an estimated ice reserve of 11.9 km³.

The Chamkhar Chu emerges from the glaciated terrain south of the water divide separating Tibet from Bhutan's northern territory. It has one western branch and two eastern branches. The western branch has its source from the glaciers of the Gangkar Punsum region and the eastern branches have their sources from the glaciers south of the Monla Karchung La Range.

At the source of the Chamkhar Chu western branch, several glaciers exist. The largest glacier is a valley glacier (cham_gr 25) lying east of Kang Ri Summit (7,239 masl) at an elevation of 4,582 masl. This glacier occupies an area of 26.71 sq.km and is 8.9 km long. The Chamkhar Chu eastern branch also has many glaciers at its source, the largest again is a valley glacier—Cham_gr 71 (Chubda Glacier). Within this glacier there are several supraglacial lakes which were observed during an expedition in August 1999 (Karma 1999).

The Chamkhar Chu flows southwards almost parallel to the Mangde Chu through the Jakar Valley. It joins the Mangde Chu near Kalamti and flows as the Mangde Chu to join the Dangme Chu in the southwest of Panbang to form the Manas River.

At the source of the Chamkhar Chu, 90 glaciers have been identified, with an estimated ice reserve of 8 km³. In the Chamkhar Chu Basin, 557 lakes exist, 306 of them are valley lakes. The largest lake is a supraglacial lake (Cham_gl 383) and is 2.6 km long.

The Dangme Chu consists of the Kuri Chu and the Gongri Chu. The Kuri Chu headwater in Tibet consists of a northern and a southern branch. The Kuri Chu flows eastwards and enters Bhutan 8 km (aerial distance) southwest of Bod La.

Within Bhutan the Kuri Chu has two main tributaries, the Bahilung Chu and the Khoma Chu. The Kuri Chu flows south through deep narrow gorges to join the Dangme Chu south of Tsegpa in Mongar. It then joins with the Mangde Chu to form the Manas River.

At the source of the Kuri Chu within Bhutan there are 51 glaciers having a cumulative surface area of 87.62 km³. In this sub-basin 179 lakes were identified, the largest lake has a surface area of only 0.9 sq.km.

The Gong Ri, the other main tributary of the Dangme Chu also has its source in Tibet, northeast of the Karchung La-Phomeje La water divide. The Gong Ri has a western and an eastern branch in Tibet. These two branches merge near Phasinadang, where the river enters Bhutan. In Bhutan the two main tributaries of the Gong Ri are the Kholong Chu flowing south through Trashigang and the Gam Ri flowing west through the Sakteng Valley. The Kholong Chu joins the Gong Ri at Duksum and the Gam Ri further downstream to form the Dangme Chu. The Mangde Chu and the Dangme Chu merge to form the Manas River which flows out into the Indian plain near the Manas forest check post.

The Nyere Ama Chu basin

The Nyere Ama Chu is the easternmost river basin in Bhutan. This river has no glaciers associated with it. In this basin there are only 9 lakes. All these glacial lakes are small. The largest among them is only 185m long.

The Northern basin

The rivers of this basin originate from the watershed of Bhutan and flow north towards Tibetan territory. Details of the rivers of this basin are not available.

3.2 HYDRO-METEOROLOGICAL OBSERVATION

Meteorological observation

In Bhutan there are more than 80 meteorological stations. Most of them are located in the south and central parts of the country.

- Climate stations (more than 60 in number) are spread all over the country. They measure daily rainfall, daily maximum and minimum temperatures, and relative humidity.
- Agro-meteorological stations (12 in selected sites) measure rainfall, rainfall duration and intensity, maximum and minimum temperatures, relative humidity, wind speed and direction, hours of sunshine, cloud cover, soil temperatures at 5, 15, and 30 cm depths, daily evaporation, and water temperature.
- Special stations (four in number) are installed along the mountain pass along the East-West Highway. These stations measure sunshine and rainfall intensity.
- Snow gauging stations (four in number) were established in 1995 to measure snowfall depth at four mountain passes.

The collected data are compiled in a ‘Lotus’ spreadsheet. Analyses as well as data validation have not yet been done.

Hydrological observations

The hydrological stations in Bhutan are established and managed by the Department of Power. The Central Water Commission (India) also has established hydrological stations under their control. The stations are mainly located at or near roads or footbridges over the main rivers from where discharge measurements are carried out by the float method.

The mean annual flows of different rivers calculated from available yearly mean data are given in Table 3.1.

Table 3.1: The mean annual flows of the major river basins of Bhutan

Name of River	Location of station		Altitude (masl)	Catchment area (km ²)	Mean annual discharge (m ³ /sec)
	Latitude	Longitude			
Gongri Chu at Uzorong	27° 15' 40" N	91° 25' 03" E	570	8,569	256
Kuri Chu at Kurizampa	27° 16' 27" N	91° 11' 47" E	540	8,600	293
Chamkhar Chu at Kurihey	27° 35' 13" N	90° 44' 13" E	2,600	1,350	53.7
Mangde Chu at Tingtibi	27° 08' 44" N	90° 41' 36" E	565	3,200	150
-do- at Bji	27° 31' 31" N	90° 27' 30" E	1,860	1,390	65.7
Sankosh at Dubani	27° 00' 30" N	90° 04' 27" E	263	8,050	387
Pho Chu and Mo Chu at Wangdi	27° 27' 45" N	89° 54' 11" E	1,190	5,640	291
Mo Chu at Yebsa	27° 37' 59" N	89° 49' 03" E	1,230	2,320	116
Ha Chu at Damchuzam	27° 21' 41" N	89° 18' 14" E	2,690	336	10.6
Wang Chu at Tamchhu			1,990	2,520	65.7