August 2012 cloudburst and subsequent flash flood in the Asi Ganga, a tributary of the Bhagirathi river, Garhwal Himalaya, India

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Asi Ganga, a tributary of Bhagirathi river located upstream of Uttarkashi township witnessed a massive flash flood on the night of 3 August 2012 due to cloudburst that occurred at the Pandrasu ridge that serve as a water divide between the Yamuna and Bhagirathi rivers. The flash flood claimed the lives of 35 human beings and 436 livestock, and affected about 12,000 people, damaging property worth about Rs 612 crore. It has been observed that most of the damages in the area is related to the physiographic disposition of the Quaternary deposits lying along the valley slopes. The continued and recurring flash floods in the Himalaya call for a Disaster Management Policy that needs to be undertaken in the Himalayan terrain. The present study lays the foundation for further work to link/map the Quaternary deposits lying loose on both sides of the river vis-à-vis any developmental activity in the Himalayan terrain.

Keywords: Cloudburst, flash flood, Garhwal, Himalaya.

ACCORDING to the India Meteorological Department (IMD), cloudburst is a natural phenomenon and is characterized by high intensity rainfall, usually more than 10 cm per hour, within a short span of time, over a small area. In the mountain regions, the sites where clouds are confined in a closed valley are the ideal sites for the occurrences of cloudbursts. The orographic peculiarities of these sites create movement of warm and moisture laden cold currents and generate localized cyclone leading to the high intensity rainfall, generally described as cloudbursts.

In the Himalayan region, cloudburst is a recurring phenomenon. It has been noted that in the recent years the intensity and the frequency of the cloudbursts have increased many folds. Often these cloudbursts, associated with flash floods and mass movement are the cause of concern, as these create havoc, particularly in the downstream region.

Sah and Mazari[1] report that cloudbursts in the Himalaya usually take place during the monsoon period between late June and early September and are generally restricted to the headwater area of the closed tributary valleys. Their frequency is more during July and August when the monsoon fully sets in the Himalayan region. The flash floods related to cloudburst and or extreme rainfall events in the Himalayan region have been described by number of workers[2–7]. Cloudbursts during August 1998 at Chirgaon (Yamuna valley), August 1999 at Ukhimath (Mandakini valley) and Malpa (Kali valley), August 2001 at Gona (Birehi Ganga valley), August 2002 at Budha Kedar (Balganga valley) and September 2012 at Ukhimath (Mandakini valley) are some of the examples of recent cloudburst events associated with flash flood and mass movements in the Garhwal Himalaya[2–5,7,8].

In the present communication, we report a cloudburst that occurred on 3 August 2012 night on the NE–SW trending spur that divides the catchment of the Yamuna river and the Bhagirathi river and the subsequent flash flood in the Asi Ganga river and the Suwari Gad, the tributaries of the Bhagirathi river. The impact of this flash flood on the slope stability in the area has also been described.

The study area covering a part of the Bhagirathi river basin lies in the Uttarkashi district of Uttarakhand (Figure 1). In the northern part, it is bounded by the NE–SW trending ridge, named Pandrasu Dhar, located at an altitude ranging between 4000 and 4800 m asl. This ridge serves as a water divide between the catchment of the Bhagirathi river and the Yamuna river. The Asi Ganga river originating from the Dodi Tal (lake) is located on the southern slope of the ridge, at an altitude of about 3075 m asl. It is called Dodital Gad and Binsi Gad in the upper reaches, Kaldi Gad in the middle and Asi Ganga in the lower most reach. It joins the Bhagirathi river near Gangori at an elevation about 1132 m asl. En route, it is fed by several streams on either side. Devkund Dhar is another ridge located further south of the Pandrasu Dhar at lower elevation, ranging between 3650 m and 4287 m asl. It serves as a water divide between the catchment of the Asi Ganga and the main Bhagirathi river (Figure 1). Number of villages like Agora, Kaldiya, Utro and Gangori are located on either side of the Asi Ganga about 10–50 m above the river bed. Suwari Gad joins the Bhagirathi river about 4 km upstream of Bhatwari. Two hydropower projects, one at Maneri and another at Joshiwara are located along the Bhagirathi river in the area for which discharge data is available.

The area under study occupies a complex geological and tectonic set-up. The northern part of the area lies in the Main Central Thrust (MCT) zone that demarcates the Higher Himalaya from the Lesser Himalaya. South of the village Agora lies in the Lesser Himalaya. The MCT zone is divisible into Lower Crystallines (Chail Group), Middle Crystallines (Jutogh Group) and the Upper Crystallines (Vaikrita Group) which are separated from one another by MCT-1 (Chail Thrust), MCT-2 (Jutogh Thrust) and MCT-3 (Vaikrita Thrust). This MCT zone has also been designated as Higher Himalayan Crystalline Zone (HHCZ). The dominant rock types constituting this

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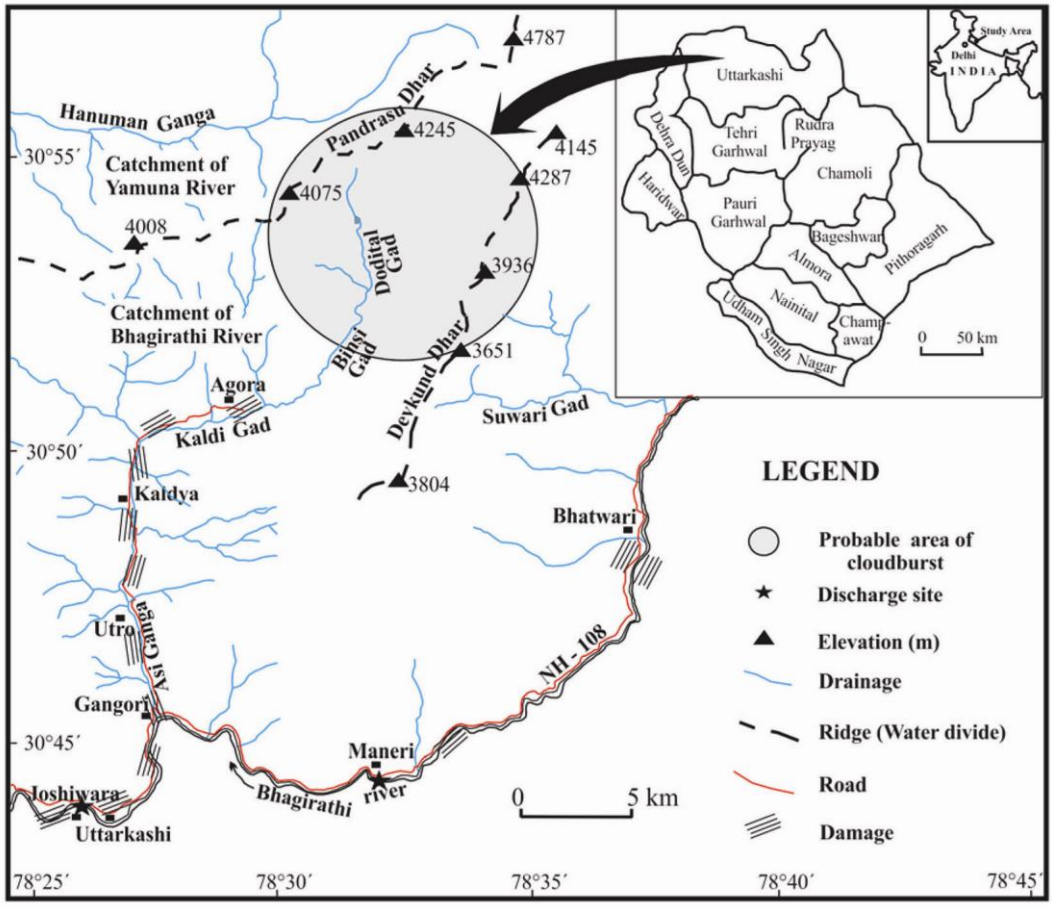

Figure 1. Location map of the area depicting the probable area of cloudburst along with the spatial location damages caused by it.

zone are mainly quartzo-feldspathic gneiss for the Upper Crystallines, calcsilicatic gneiss, biotite gneiss and migmatitic gneiss for the Middle Crystallines and chlorite schist, schistose quartzite and augen gneiss with bands of the metabasics for the Lower Crystallines. The rocks of the Lesser Himalaya have been designated as Garhwal Group and mainly consist of quartzite with bands of limestone, chlorite schist and metabasics. The details about the geological set-up of the study area and its environs have been discussed by Purohit *et al.*[9].

Geomorphologically, the entire Asi Ganga valley depicts a highly unstable topography as indicated by high relief and active erosional processes. The total relief along the valley slopes is about 1000 m, and the total relief of the area is about 3000 m. Among the geomorphic processes, fluvial processes have played a dominant role in shaping the present landscape. Most of the currently prevailing processes in the area are denudational, but nonetheless, few of their complimentary depositional features also occur. The valley slopes are generally steep with an angle varying between 50° and 80°.

Climatically, the study area lies in the sub-humid to humid temperate zone in the upper reaches and the humid zone in the lower. Daily rainfall data from 2006 to 2012 available for Bhatwari indicate that the annual total rainfall in the area is about 1369 mm with ~65% rainfall occurring during the monsoon season, i.e. during the months of July, August and September.

The hourly discharge data of the Bhagirathi river at Maneri Dam site from January 2012 to October 2012 was available. In addition, the hourly discharge data at Joshiwara Barrage site from 2 to 5 August 2012 that depicts the discharge before and after the flash flood was also available. Since Maneri is located upstream of Asi Ganga–Bhagirathi river confluence, the discharge data at Maneri reflects the unusual discharge of the Suwari Gad, and the discharge data at Joshiwara reflect the combined discharge of the Asi Ganga and Suwari Gad. Thus, the discharge of the tributary Asi Ganga has been obtained by subtracting the Maneri discharge data from the discharge data at Joshiwara.

The average daily discharge of the Bhagirathi river at Maneri from 15 June to 21 September 2012 has been depicted in Figure 2 *a*, whereas Figure 2 *b* depicts the hourly discharge of the Bhagirathi river at Joshiwara, Maneri and Asi Ganga for 2–5 August 2012. It has been observed that there is an unusual high discharge on 3 and 4 August and the discharge at Joshiwara abruptly

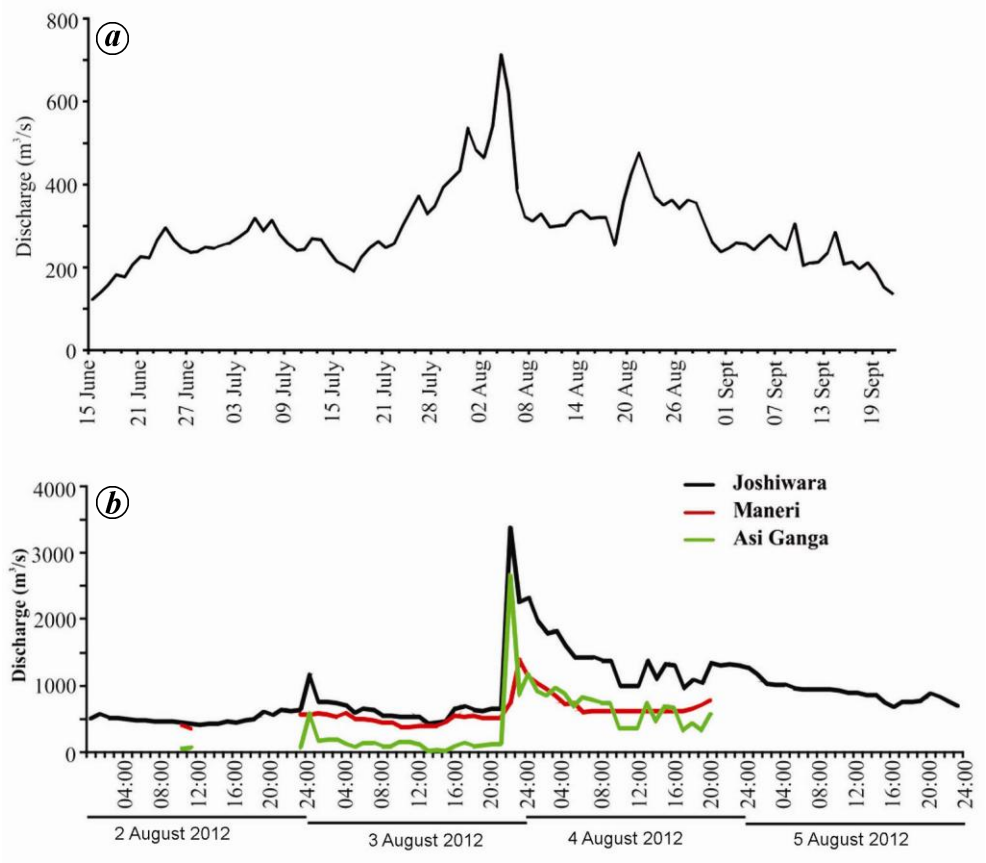

Figure 2. ***a***, Average daily discharge of Bhagirathi river at Maneri from 15 June–19 September 2012 (Note the abnormal discharge on 3 August, secondary peak has also been observed on 21 August). ***b***, Hourly discharge of Bhagirathi river at Joshiwara (depicting combined discharge of Asi Ganga and Suwari Gad), Maneri (depicting discharge of Suwari Gad) and Asi Ganga during 2–5 August 2012.

Table 1. The loss and damage to lives and infrastructure due to 2012 Asi Ganga flash flood in the Bhagirathi valley

Item	Loss
Number of human lives lost	35
Number of livestock lost	436
Total area of the land lost	61.78 ha
Damage to houses	
Fully damaged	141
Severely damaged	149
Partially damaged	301
Total damage	Rs 61,244.12 lakh

increases in the early hours at 1:00 am on 3 August 2012. The next hour, the discharge returns to its normal value. Again at 23:00 hours, the same day, the discharge rose to about 3390 m^3/sec as compared to 662 m^3/sec the previous hour (an increase about 5 times). However, the discharge recoded at Maneri was not very high. It gradually rose from 527 m^3/sec to 725 m^3/sec at 11:00 pm and 1389 m^3/sec at 12:00 pm in the night of 3 August 2012. The maximum increase in discharge has been observed in the tributary Asi Ganga. In just one hour, it increased from 76 m^3/sec to 595 m^3/sec at 1:00 am on 3 August and at 11:00 pm it rose to 2665 m^3/sec as compared to 135 m^3/sec the previous hour.

The cloudburst occurred on the top of the Pandrasu Dhar at an elevation ranging between 4000 and 4500 m asl. As has been seen, greater amount of discharge got concentrated in the Asi Ganga that joins the Bhagirathi river at Gangori, followed by the Suwari Gad that joins the Bhagirathi river about 4 km upstream of Bhatwari (Figure 1). There are also report of flash flood, at the same time, in the Hanuman Ganga, the tributary of Yamuna river, located further north of the study area. The damages caused by the August 2012 flash flood in the Bhagirathi river catchment are briefly described below.

The direct loss caused by 2012 flash flood is restricted along the course of the Asi Ganga and the Bhagirathi river. The flash flood took a toll of 35 human lives, 436 livestocks and injured 20 people. It affected a population of 12,000 and 189 villages. An estimated 61.787 ha of agricultural land was lost. The total loss as estimated by the State Government was about Rs 61,244.12 lakh and is summarized in Table 1.

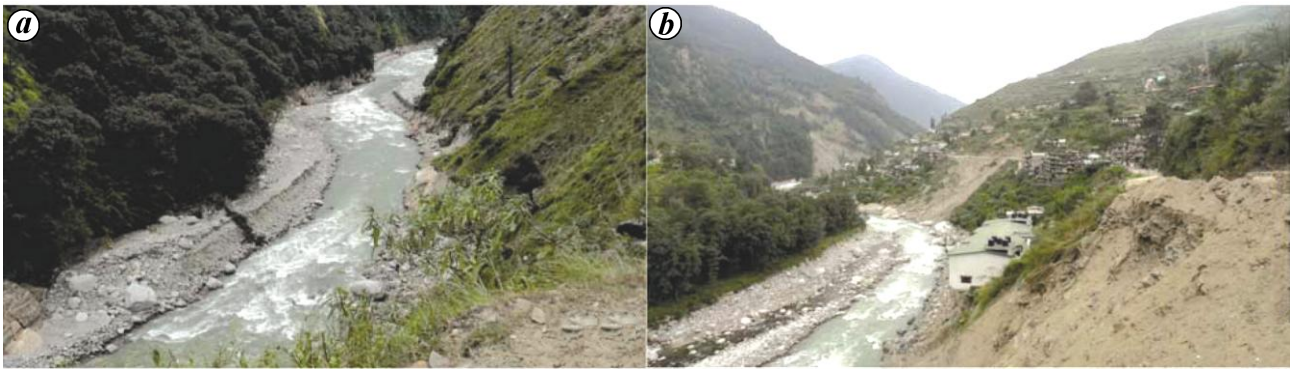

Figure 3. ***a***, 2.3 m thick material deposited by 2012 flash flood on both sides of the Bhagirathi river near the downstream of the confluence of Suwari Gad–Bhagirathi river. ***b***, Landslides generated by bank erosion in the downstream of the Bhatwari section has made the entire slopes unstable. Note the badly damaged Bhatwari Tourist Rest House.

The confluence of the Suwari Gad–Bhagirathi river is a gorge section and the water level marks have been observed about 3–4 m high above the present level of the Bhagirathi river. The flash flood deposited about 2–3 m thick river borne material of varying sizes on both sides of the Bhagirathi river (Figure 3 *a*). A bridge on the Suwari Gad had been washed away. As there is no habitation and the National Highway (NH-108) is about 60–70 m above the river section, no damage has been reported between Suwari Gad–Bhagirathi river confluence and Bhatwari, though there were number of old subsidence zones in this section. The general angle of valley slopes is about 40° and hard rocks are exposed on both banks of the Bhagirathi river. Thus freshwater marks about 3–4 m above the present level of river could be observed on both sides of the Bhagirathi river.

The bank erosion due to the flash flood is prominent in downstream of Bhatwari section, as loose material is located on both sides of the slopes. Bhatwari tourist rest house was badly damaged and also number of fresh landslides had been generated in this stretch, mainly because of the bank erosion (Figure 3 *b*). Tree logs carried by the flash flood have been observed at many places in this section of the river.

The loss incurred due to the flash flood was reported highest in the Asi Ganga tributary as the discharge got concentrated in the Asi Ganga valley. The discharge during the flash flood rose to 2665 m^3/sec as compared to normal discharge of about 100–200 m^3/sec (Figure 2 *a*). It has been observed that water level rose by about 3–5 m in the river section where the width of the river was 100–125 m. As told by the villagers, the maximum water level had risen by about 25–30 m and remained so for about 1 h downstream of the village Utro. This may be related to the formation of temporary lake along its path, as downstream, a major landslide has been observed. The breaching of the lake has also been reflected in the unusual fluctuation in discharge data after 11:00 pm (Figure 2 *b*).

The flash flood completely damaged three small hydropower projects (SHPs) namely, Asi Ganga-I, Asi Ganga-II and one in the Kalidi Gad that were under construction (Figure 4 *a*). Six bridges were either completely destroyed or damaged, including the bridge at Gangori on the confluence of Asi Ganga–Bhagirathi rivers. A high school and Trout Reproduction Centre located at village Kaldya and irrigation and power house canal at Agora on terrace deposits on the right bank of the Asi Ganga has been completely washed away (Figure 4 *b*). The complete road network from Gangori to Dodital was disrupted, with about 10 km of the road completely washed away, besides damage to the flood protection wall on the left side of the Asi Ganga in the Gangori township (Figure 5).

The flash flood has changed the geomorphology of the Asi Ganga valley. It has been observed that many sections of the river, particularly upper and the middle reaches, got filled dominantly with ~1.5–3.0 m, thick pebbles, boulders and cobbles of blackish and greenish gneisses, and few of light coloured quartzites brought by the flash flood.

Water level at the confluence of Asi Ganga and the Bhagirathi river rose to about 3–4 m in a river that has a width of about 125 m. A lot of damage has been observed in the Gangori township, in the form of washing away of Gangori bridge, and the flood protection wall (Figure 5). Number of fresh landslides have also been generated in the Uttarkashi township due to bank erosion (Figure 1). The flash flood resulted in damage to shopping complex near Tiloth bridge, national highway, sewerage line and sewerage treatment plant in the Uttarkashi township.

Cloudbursts are common in the Himalaya and are often associated with flash floods and landslides. This demands their early prediction and the development of warning system that are crucial to mitigate societal impact arising from the accompanying flash floods. Attempts are being carried out in this direction[10]. In the present case, damages to important buildings like Bhatwari rest house, NH-108, Gangori–Dodi Tal road, flood protection wall, etc. have been reported mainly because of the toe erosion of the Quaternary sediments lying along the river. A school and trout fish reproduction centre at Kaldya have

Figure 4. ***a***, Highly damaged power house located near Kaldya in the tributary Asi Ganga. ***b***, Remains of school entrance at village Kaldya that has been completely washed away.

Figure 5. Highly damaged flood protection wall on the left bank of the Asi Ganga near the confluence of the Asi Ganga and Bhagirathi river at Gangori township.

been competently washed away, as these were located on the active flood plain of the Asi Ganga river, about 3 m above the river channel.

In view of the recurring danger to life and property in the closed valleys in the Himalayan region, a proper developmental policy should be adopted to off-set any untoward incidences of hazard, which is so far lacking for all the Himalayan states. The repeated cloudbursts in the Himalayan region, well exemplified by series of cloudbursts in August and September 2012, and associated flash flood in the Garhwal Himalaya claim the evaluation of risk posed by these natural hazards along with the secondary hazards like flash flood and landslides.

1. Sah, M. P. and Mazari, R. K., An overview of the Geoenvironmental status of the Kullu Valley, Himachal Pradesh, India. *J. Mt. Sci.*, 2007, **4**, 3–23.
2. Sah, M. P. and Bist, K. S., Catastrophic mass movement of August 1998 in Okhimath area Garhwal Hımalaya. In Proceeding of International Workshop cum Training Programme on Landslide Hazard and Risk Assessment and Damage Control for Sustainable Development, New Delhi, 1998, pp. 259–282.
3. Paul, S. K., Bartarya, S. K., Rautela, P. and Mahajan, A. K., Catastrophic mass movement of 1998 monsoons at Malpa in Kali Valley, Kumaun Himalaya (India). *Geomorphology*, 2000, **35**, 169–180.
4. Naithani, A. K., Joshi, V. and Prasad, C., Investigation on the impact of cloudburst in Tehri District, Uttaranchal – 31 August 2001. *J. Geol. Soc. India*, 2002, **60**, 573–577.
5. Sah, M. P., Asthana, A. K. L. and Rawat, B. S., Cloud burst of August 10, 2002 and related landslides and Debris flows around Budha Kedar (Thati Kathur) in Balganga valley, District Tehri. *Him. Geol.*, 2003, **24**, 87–101.
6. Joshi, V. and Kumar, K., Extreme rainfall events and associated Natural Hazards in Alaknanda valley, Indian Himalayan region. *J. Mt. Sci.*, 2006, **3**, 228–236.
7. Rana, N., Sundriyal, Y. P. and Juyal, N., Recent cloudburst-induced landslides around Okhimath, Uttarakhand. *Curr. Sci*., 2012, **103**, 1389–1390.
8. Bist, K. S. and Sah, M. P., The devastating landslide of August 1998 in Ukhimath area, Rudraprayag district, Garhwal Himalaya. *Curr. Sci*., 1999, **76**, 481–484.
9. Purohit, K. K., Islam, R. and Thakur, V. C., Metamorphism of Psammo-pelitic rocks of Bhagirathi valley, Garhwal Himalaya. *J. Him. Geol*., 1990, **1**, 167–174.
10. Das, S., Ashrit, R. and Moncrieff, M. W., Simulation of a Himalayan cloudburst event. *J. Earth Syst. Sci*., 2006, **115**, 299–313.

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