Hazards of Erosion and Sedimentation Due to Cloud Burst in Small Catchments - A Case Study from Kumaun Himalayas, India

R. Anbalagan
University of Roorkee,
Roorkee-247667, U.P., India

Abstract

The highly rugged Himalayan terrain often faces extreme hydro-meteorological conditions of the type leading to flash floods and their consequent devastation. The temporal and the spatial variations in such extreme rainfall constitute the chief determinant factors of the floods. A cloudburst comes with the speed of thunder and may last for a few minutes or a few hours. The impact is all the more ravaging if the area involved is a small catchment characterised by steep hill slopes and high riverbed gradients.

The most important adverse effect of a cloudburst is the triggering of large-scale mass movements, which introduce enormous amounts of sediment into the drainage system (Carson 1985). The consequences of large-scale erosion due to a cloudburst in small catchments is twofold - i) the excessive sediment load may cause aggradation conditions of the riverbed further downstream, thereby increasing the water level in general and flood hazards in particular (Pal and Bagchi 1975) and ii) the debris, including big boulders resulting from the sudden and large-scale erosion, may temporarily dam the river. Any subsequent breaching may cause a devastating surge of water, leading to excessive mass movements along its course and causing widespread damage to life and property. The disastrous events triggered by a cloudburst in July 1983 in Karmi village of Almora Kumaun are discussed.

Cloudbursts and Gully Erosion

Gullies are long, narrow, and deep channels, usually having steep gradients (>30°) and very steep side slopes (>60°). Water flows through these channels, which generally have a small catchment only during rains. The gullies are usually first- and sometimes second-order streams.

Gully erosion is one of the major environmental hazards in the Himalayas, particularly in the Lesser and Higher Himalayas. During cloudbursts, the gully erosion often has highly devastating effects in the form of debris flow and landslide dams.

Since, during cloudbursts, the surface runoff water is excessive and continuous, it oversaturates the top layer of soil or debris below, leading to a shallow perched water table rising up to the surface. This reduces the grain-to-grain or block-to-block contact of the slope materials below. Such conditions may often lead to failures of the slopes. Under extreme conditions, it may result in debris or soil flow.

The debris flow of colluvium or torrent deposit along the gullies takes place at a tremendous velocity, ranging between 1 and 10m/sec (Deoja et al. 1991). Moreover, the viscosity of the water increases rapidly (Baverage and Culbertson 1964). Sasa (1985) has shown experimentally that the fine particles (mud) become suspended in water because of the eddy currents of rapid debris flow. Consequently, the unit weight of the pore fluid rises from 1 to 1.6gm/cc depending upon the flow velocity and clay content. This causes the factor of safety to drop to one/fifth of the value in dry conditions. Because of the increased velocity and viscousity of the water, the capacity to carry heavy boulders increases many times. The maximum size of the boulders that can be transported by this abnormal drag force is in the order of 1.8m (Deoja et al. 1991). The above conditions explain the capacity of the debris-charged water to carry exceptionally big boulders along the gullies.

The flow of debris may be arrested in a narrow valley, due to the big boulders, and lead to a landslide dam. The impoundment of rainwater behind such a dam may cause floods upstream, while its breaching may lead to flash floods downstream. The stability of these dams depends on a number of factors such as the volume, texture, sorting of the dam materials, capacity of storage, nature of seepage water, rate of sedimentation, and amount of water flow into the lake. Depending on such conditions, these dams may be breached from within a few hours to up to a few years. However, if the dam is formed within the gully itself then, due to the very limited storage available, it often is breached within a few hours, resulting in flash floods and large-scale devastation in the form of loss of life and the triggering of landslides.

Hazards of Cloudbursts in the Karmi Stream, Kumaun Himalayas

Though most parts of the Himalayas are vulnerable to cloudbursts, the event described here is in a special category because of its disastrous consequences. It is a tragic case of debris flow impacting on the human encroachment into the stream bed, leading to the formation of a landslide dam and its consequent breaching.

The tragedy struck a sleepy village, Karmi, in Almora district of the Lesser Kumaun Himalayas, on the night of July 22, 1983, initially in the form of a cloudburst (Anbalagan 1983). The village of Karmi is connected by a 23km-long bridle path from Barari, a place well served by an all-weather motor road to Bhageshwar, the *taluk*[1] headquarters (Fig. 1). The area falls within the Survey of India toposheet No.53 N/16. The stream passing through this village, the Karmi, has a small catchment just above the village.

Physiography and Geology of the Area

The village of Karmi, located along the stream, has two clusters of settlements - a major one located to the east of the stream, with many scattered houses, and the other one located to the west, with only a few houses. While the houses on the eastern side are located away from the stream bed, the ones to the west are

[1] *Taluk* - district

situated on a terrace adjoining the stream (Fig. 2). The originally wide stream course had been obstructed by the construction of the terrace, which forced the stream to flow through a very narrow section.

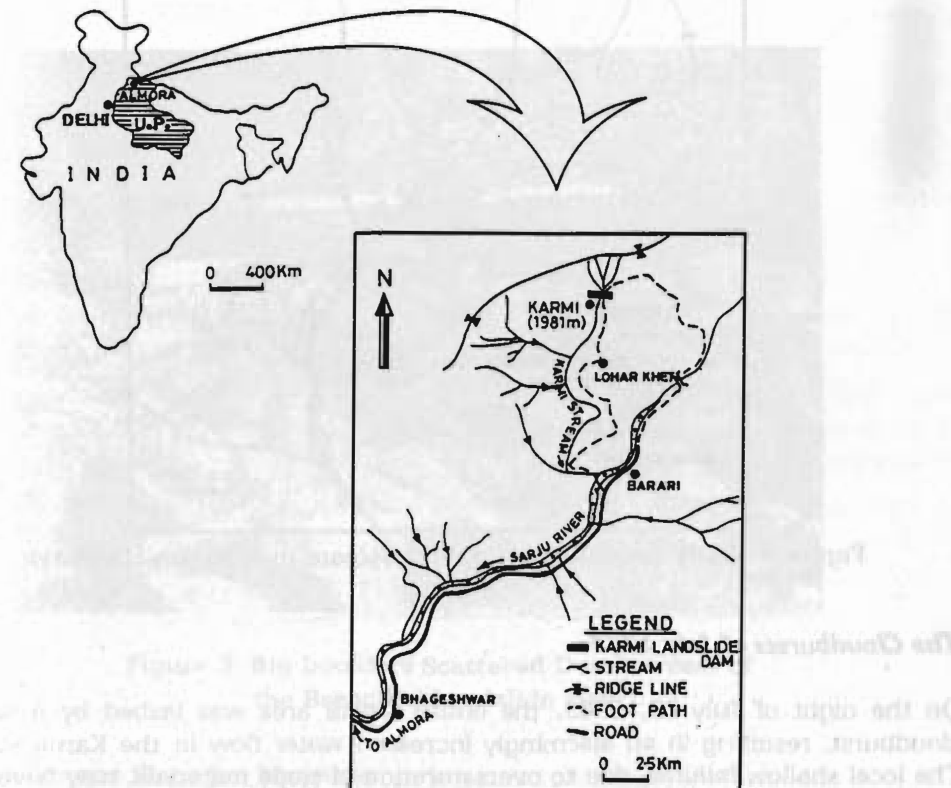

Figure 1: Location of Karmi Landslide

The small catchment of the Karmi above the village features a NE-SW trending, arcuate, narrow ridge with steep slopes that runs from north-east to south-west. The south-easterly descending gullies on the ridge are mostly first-order in nature, with very steep slopes (45°). These gullies join together further down to form the Karmi stream. The stream locally has a flat slope of 5°-10° in the vicinity of the houses, but further on it increases to 20°-25° and then joins the Saryu River about three kilometres downstream from Barari village.

The rocks exposed on the steep ridge behind Karmi village include quartzites with bands of mica schists. The foliation, the main structural discontinuity, strikes at N20° to 40°W - S20° to 40°E and dips about 50° in a north-easterly direction. However, the strongly developed joints control the steep south slopes of the narrow ridge.

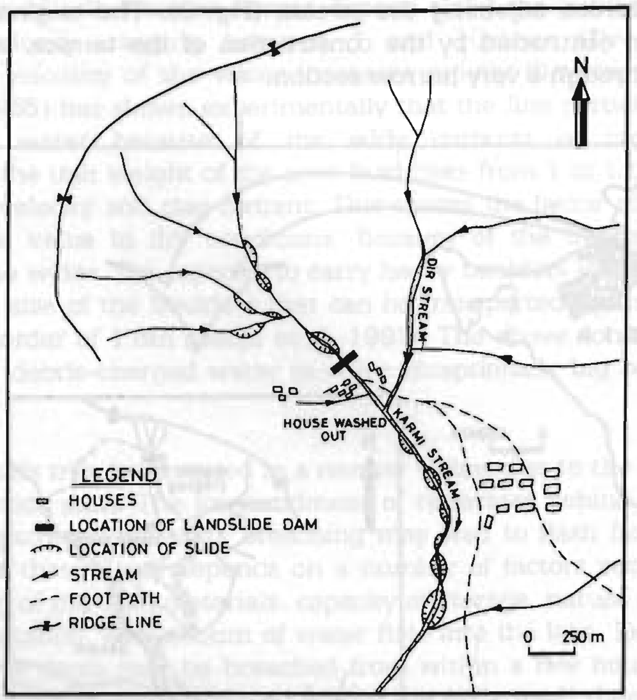

Figure 2: Gully Erosion along Karmi Stream in Kumaun Himalaya

The Cloudbursts of July 1983

On the night of July 23, 1983, the entire Karmi area was lashed by a sudden cloudburst, resulting in an alarmingly increased water flow in the Karmi stream. The local shallow failures, due to oversaturation of slope materials, may have been what caused the debris flow to uproot big boulders on its way. The mobilised slope materials became arrested in the encroached portion of the stream, creating a landslide dam of about 40m behind the terrace on which the houses are located. Since the catchment behind the dam was very limited, it was breached within a few hours. As the whole event took place in the night amidst a powerful downpour, the dangerous developments did not come to the notice of the people of the area.

Devastating Damage due to Cloud Burst

The bursting of the landslide dam resulted in the blocked materials being swept downstream as well as flash floods in the lower reaches. Since the terrace on which the houses were located is just below the dam location, the houses were simply wiped out, resulting in heavy loss of human life and cattle (Table 1). The impact was so sudden that the houses located away from the disaster site did not even learn of the tragic event till morning. The debris carried along with the flash flood also buried a part of the terrace and the adjoining agricultural lands (Fig. 3). The surging water charged with debris played havoc further downstream causing excessive gully bank erosion on either side and leading to a series of landslides (Fig. 2) in the initial four kilometres.

Table 1. Nature of Damage Due to Cloud Burst in the Karmi Area

1.	No. of houses washed away	6
2.	No. of missing persons	25
3.	No. of cattle lost	20
4.	Nature of damage to agricultural lands	Landslides adjoining the gully

Figure 3: Big Boulders Scattered Downstream of the Breached Landslide Dam

Conclusions and Remedial Measures

The cloudburst is one of the major natural hazards in the Himalayas, occurring amid extreme hydro-meteorological conditions. It strikes at random and at a lightening speed, generally lasts for a limited time, and leaves behind a trail of devastation.

The debris flow often associated with a cloudburst is initiated due to oversaturation and resultant shallow landslides. The debris flow has a tremendous capacity to transport big boulders, which may in turn block the movement of mobilised materials in narrow gully/stream sections leading to landslide dams.

The breaching of landslide dams due to flash floods may have dangerous consequences, including loss of human life and property.

The population pressure in hilly regions has been mainly responsible for the settlement of hazardous areas in them. A most convenient but very unsafe location is among the valley fill material close to stream courses, particularly gullies. People in hilly areas should be educated about such dangers by non-governmental agencies.

Since the gully/stream erosion in the Karmi area has left a series of landslides on banks both upstream and downstream from the dam location, it is essential to check further erosion of the gully bed by constructing check dams in suitable locations and to minimise erosion of the banks by erecting gabion walls along them.

References

Anbalagan, R., 1983. 'A Geotechnical Note on the Slides around Karmi Village, near Kapkot, Almora District, Uttarpradesh. Unpublished report of the Geological Survey of India. Calcutta: India.

Baverage, J.P. and Culbertson, J.K., 1964. 'Hyperconcentration of Suspended Sediments'. In *Journal of Hydraulics Division. Amer. Soc. Civil Eng.* 90 (HY6), 117-128.

Carson, B., 1985. *Erosion and Sedimentation Processes in the Nepalese Himalaya.* ICIMOD Occasional Paper No. 1. Kathmandu, Nepal: ICIMOD.

Deoja, B.; Dhital, M.; Thapa, B.; and Wagner, A., 1991. *Mountain Risk Engineering Handbook,* Parts 1 & 2. Kathmandu: International Centre for Integrated Mountain Development, Kathmandu.

Pal, S.K. and Bagchi, K., 1975. 'Recurrence of Floods in Brahmaputra and Kosi Basin: A Study in Climatic Geomorphology'. In *Geographical Review of India* 37, 242-248.

Sasa, A., 1985. 'The Mechanism of Debris Flow'. In *Proceedings of the Eleventh International Conference of Soil Mech.,* 1173-1176: San Francisco: Foundation Engineering.