

Landslide disaster on Berinag–Munsiyari Road, Pithoragarh District, Uttarakhand

S. Sarkar and D. P. Kanungo

The landslide disaster on 8 August 2009 near Kuity village in Pithoragarh district of Uttarakhand State buried two villages and took 43 lives. The landslide, triggered by cloud burst resulted in massive debris flow along a stream channel. The site is still in danger as shown by the presence of huge quantity of debris and ground cracks on the slope. Here we present inferences drawn from the field observations.

A landslide disaster occurred on 8 August 2009 near Kuity village on Berinag–Munsiyari road of Uttarakhand State. The precise location of the slide area is lat. $30^{\circ}01'17.46''\text{N}$ and long. $80^{\circ}08'58.75''\text{E}$ at 7 km from Kuity village and at an elevation of about 1600 m (Figure 1). The landslide wiped out two villages namely Jhakhla and Lah, claiming 43 lives. It can be treated as one of the most severe landslide disasters of recent times, comparable to the Malpa landslide in 1998, the Phata landslide in 2001 (ref. 1) and the Uttarkashi landslide in 2003 (ref. 2).

The recent slide was triggered by a cloud burst which caused massive debris flow along the stream called Paniyali Gad which flows from west to east and meets the Jakula river which flows from north to south and meets the Ramganga near Tejam. The houses situated on downhill slope below the road were completely ruined. The debris came down from the higher reaches of Paniyali Gad and after destroying the road and the villages deposited on the downhill slope. The impact of debris flow was so intense that, within no time, all the residents of the villages were buried under a thick pile of debris. A rapid survey of the area

was undertaken on 18 August. Here we present field observations during the survey, probable causes of the slide and the associated risk in the area. A panoramic view of the landslide is shown in Figure 2.

Geology and slope instability

Geologically this area belongs to Calc Zone of Tejam Group of rocks in the vicinity of Munsiyari Thrust (Main Central Thrust) belonging to Deoban and Mandhali formations mainly comprising dolomite and argillaceous limestone³. Rocks exposed in the area are primarily dolomites. These rocks are degraded by intense fracturing and shearing by the tectonic activities and subjected to severe erosion by the streams continuously eroding and dislodging rock boulders and debris from the parent rocks. The landslide debris comprises huge boulders and rock fragments along with water saturated soil mass.

Many landslides are observed in the surrounding region. A major landslide was observed on the higher slope on the left bank of the Jakula river while the present landslide occurred on the right bank of the river. These indicate that the area is very susceptible to landslide occurrences. The pre-landslide sce-

nario of the region as observed in the satellite image available in the recently launched Bhuvan, Indian Earth Observation Visualization (IEOV) has clearly indicated that the Paniyali Gad stream has loose earth material. From this image, it can also be inferred that probably a small landslide scar at higher reaches of the stream was present prior to the recent event (Figure 3).

Landslide features

The main escarpment of the landslide was developed at a height of about 80 m above the road level and at a sloping distance of about 200 m. This is a rough estimation as the crown section of the slide was not clearly visible. There are many secondary scars along the stream which were developed due to the impact of debris flow and erosion by the rapid water flow along the channel. The debris moved down along the narrow path in a 10–15 m wide channel. The toe of the slide at river level has a thick pile of debris deposited in a fan shape on a gentle slope. The debris volume resting on the downhill slope is estimated to be of the order of 200,000 cubic metres (Figure 4).

The flow direction is 130°N along the hill slope. The average slope angle is about $20\text{--}25^{\circ}$ above the road level while

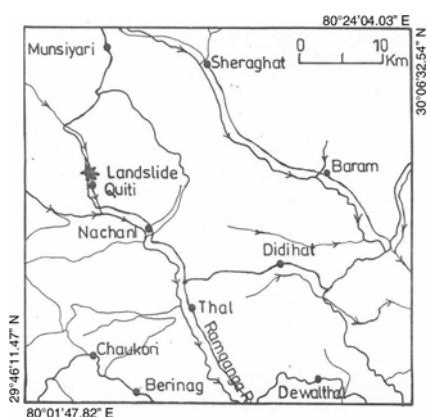


Figure 1. Location map of landslide.



Figure 2. Panoramic view of the landslide.



Figure 3. Pre-landslide scenario as seen in Bhuvan satellite image.

the debris resting on the slope below the road is about 30° . The right flank of the slide along the channel has fractured and jointed rocks dipping 25° towards 20°N . The slope is very steep on the right flank. On the left flank, the slope has agricultural land having a general slope angle of $20\text{--}30^\circ$. The slope has a thick soil cover with occasional rock outcrops. Numerous ground cracks have developed on this slope due to the landslide (Figure 5). The cracks are transverse and longitudinal and a few of them are visible up to 1 m deep and 40–50 cm wide. The cracks seem to be active and still widening. This clearly indicates that the slope is still active.

Landslide causes and mechanism

The prime cause of the landslide was an unprecedented heavy rainfall often termed as cloudburst. It seems that the slope before the slide must have been in a marginally stable condition due to erosion by the stream, weakening the weathered geological strata overlain by loose rock boulders. The other preparatory factors could be the neo-tectonic activities as the area is close to MCT.

As observed from the Bhuvan satellite image of pre-landslide scenario of the area, it is inferred that a landslide escarpment existed on the upper reaches of the Paniyali Gad stream. The stream flows towards NE direction up to the road level and changes its direction towards east below road level. Before meeting Jakula river, the stream gets bifurcated into two different channels. Lah village is situated close to the river bed between these two channels and Jhakla village is situated on the northern side/left flank of the Paniyali Gad stream just below road level.

From the field observation, it is inferred that the slide might have been

initiated with the dislodging of loose overburden material saturated with water and scouring of adjoining slopes producing a huge quantity of debris after the heavy downpour. The accumulation of debris in the narrow channel may have blocked the channel for a short duration creating very high hydrostatic pressure. This could have resulted in complete failure of adjoining slopes, adding more debris which ultimately flowed down with the water along the narrow channel. Because of the confined narrow channel with a $25\text{--}30^\circ$ slope carrying a huge amount of debris in the form of slurry, the flow occurred with a very high velocity and further eroded the left flank of the stream above the road level. The water charged with enormous quantity of debris could not deposit its load till it reached the road level after which the debris spread on the downhill slope. This can be very well explained by the morphology of the slide area which indicates that there is a topographic control over the landslide process and damage. As the debris reached the road level it again started flowing down the slope in the form of the debris and mud flow while

depositing part of the debris on its way down the slope. In this process the debris washed away Jakhla village located just below the road. Further down slope, the debris flowed and deposited as a fan engulfing Lah village before reaching the river level.

Risk assessment

The existing cracks on the ground, presence of huge quantity of debris, and heavy water flow along the stream channel indicate the severity of the landslide. The ground cracks have shown indications of further potential movement in the area. There are a few houses located on this slope. Two houses situated on the left flank are partially damaged (Figure 6). These damaged houses near the slide area have been vacated while people are still staying in the houses a little away from the slide area.

The house below the road level has developed many cracks on the floor and walls. The local people told us that these cracks are still developing and widening. The house on the uphill slope has also



Figure 5. Ground cracks on the left flank developed due to landslide.



Figure 4. Debris accumulation on downhill slope below road level.



Figure 6. Damaged houses.

developed many cracks. One wall has been completely detached from the roof. The front wall has moved ahead showing a differential movement.

Several cracks were observed on the slope and it was found that the cracks are still widening which shows the existing slope instability condition of the area (Figure 5). These cracks can serve as openings for rain water to infiltrate and create pore pressure, which may further aggravate the slope instability. The houses on the other slopes are far from the present landslide and separated by a major stream. It is difficult to comment at this moment whether all these houses are in danger due to the present sliding activity. However, the adjoining slopes on the left flank can be treated as completely unstable and no one should live or work there. Since there is still huge quantity of debris in the form of boulders, rock fragments and soil mass fully saturated with water present along the

channel above the road (Figure 7), the site is still at risk particularly for traffic. On the day of survey it was also observed that water is still flowing along the channel carrying mud and fine debris. Further, the slip zones adjoining the channel may aggravate the situation during heavy rains.

The site also has potential to create landslide dams. If the huge debris accumulated on the downhill slope flows further up to the river level, a temporary landslide dam may develop which can ultimately form a temporary reservoir affecting the upstream catchment of Jakula river and result in subsequent flash flood damaging the downstream of Jakula river (Figure 8).

Conclusions

The recent landslide disaster of 8 August 2009 on Berinag–Munsiyari road was due to massive debris flow triggered by heavy downpour killing 43 lives. The presence of huge debris along the stream and below the road and the ground cracks on the uphill slope has indicated that the area is still under considerable risk to life and property. The site needs a detailed investigation to suggest some suitable remedial measures to protect the debris and to stabilize the unstable mass above the road level.

The landslide event has sent a strong signal for the urgent need of landslide risk analysis. Such a type of massive landslide hazard cannot be prevented, but the consequences can be minimized if there is proper risk estimation and planning prior to such a major event. It is a well-known fact that there are numerous major active landslides which may cause disaster in the event of a major rainfall or earthquake. Further, there are many potential landslide slopes which have large volume of debris and rock boulders threatening to come down as massive debris flow or rock fall. With the help of high resolution satellite data, source

zones of these landslides can be identified and terrain features along with geomorphological characteristics associated with the landslides can very well be mapped. The landslide debris along with catchment characteristics may lead to assess the debris flow hazard. The risk elements which are essentially the lives, buildings, roads and other property can then be evaluated to determine the risk from these landslides. A study of this kind will help in landslide risk assessment in the area. Further, a dense network of rainfall station should be installed particularly in the areas with a past history of cloudburst. Monitoring rainfall, landslide warning can be transmitted to landslide-prone areas with high risk during heavy downpour. Such studies will lead to efficient landslide disaster management.



Figure 7. Debris on uphill slope above the road.

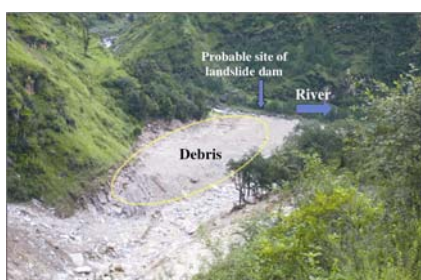


Figure 8. Risk of forming landslide dam.

1. Sarkar, S., Kanungo, D. P. and Jethi, A. K., Landslide hazard and risk in Uttaranchal. All India Seminar on Infrastructure development in Uttaranchal problems and prospects, Institution of Engineers, Roorkee, 2001.
2. Sarkar, S., Kanungo, D. P. and Chauhan, P. K. S., *Curr. Sci.*, 2004, **87**, 134–137.
3. Valdiya, K. S., Geology of the Kumaun Lesser Himalaya, Wadia Institute of Himalayan Geology, Dehradun, 1980, p. 291.

ACKNOWLEDGEMENTS. We thank the Director, Central Building Research Institute for his valuable suggestions and for granting permission to publish this paper. We also thank Mr Harish Kumar for field photography and Mr B.S. Bisht for assisting in the field survey. The technical discussion with Dr P. K. Champati Ray, IIRS, Dehradun is acknowledged.

S. Sarkar* and D. P. Kanungo are in the Central Building Research Institute, CSIR, Roorkee 247 667, India.

*e-mail: shantanu_cbri@yahoo.co.in