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Damming Rishiganga in Chamoli District on the aftermath of Flash Flood Disaster of February 7, 2021: Case Study

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Abstract

Initial flash flood event of February 7, 2021 occurred in Raunthi Gadhera that originates from Nanda Ghungti peak (6309 m) and flowing from South to North meeting with Rishiganga at an elevation of 2315 m asl at right angle. Flooded water in a huge amount flowed down through the same that damming at the confluence of Raunthi Gadhera with Rishiganga. Wherein back flowed of water saturated bouldary debris together with ice chunks along the Rishignaga upto 500 m. After breaching of temporary dam at confluence, this left behind a huge amount of sediments over Rishiganga upto at an elevation of 2389 m asl and blocked the course of the same resulting in an artificial lake is formed. Flooded water gushing down along the Rishiganga washing away a functional hydropower project of 13.2 Mw capacity on Rishiganga upstream of Rini and to the downstream severe damage under construction hydropower project of 520 Mw of National Thermal Power Corporation (NTPC) at Tapoban on Dhauliganga river. Apart from these washing away 5 pedestrian bridges over Dhauliganga river along with 1 RCC motorable bridge over Rishiganga. 204 people went missing, including 9 inhabitants and 2 Police personnel, of these body of 83 people could be recovered. The study highlights causes of lake formation and suggestions for mitigating future threat from the same in downstream.

Keywords: Flash flood, Narrow gorge, Paleo lake, Dhauliganga valley, Nanda Devi massif and Higher Himalaya

1. Introduction

The state of Indian subcontinent of Uttarakhand located in the center sector of the Himalaya has a long disastrous history before its creation because of hydrometeorology, fragile geology, adverse topography and high seismicity resulting in numbers of natural hazards occurred in the same region. Some of the major disastrous events which occurred over the past in this region wherein a numbers of fatalities had happened are Sher-Ka-Danga landslide of 1880 killing 151 people, Uttarkashi earthquake of 1991 killing 768 people, Okhimath landslide of 1998 killing 101 people, Malpa landslide of 1998 killing 221 people, Chamoli earthquake of 1999 killing 100 people (Atkinson,1886; Kumar and Mahajan, 1994; Bist and Sah,1999; Paul et al., 2000; Jain et al., 1999)1 Apart from, a number of streams like Kali, Bhagirathi, Alaknanda, Mandakini rivers and their tributaries have been blocked manifold due to rock fall, debris slide, debris flow, avalanche and moraine/glacier sediments in the region (Khanduri, 2021). Subsequent breaching caused enormous loss of life, property and infrastructure into downstream.

Landslides are however occurred due to inherent geology, multiple quakes together with steep slope, high relief, frost action and rainfall. Earlier, a number of hill slopes of Uttarakhand have witnessed massive landslides related incidences. These include (i) in year 1857, a massive landslide reportedly blocked the flow of the Mandakini river for three days in Rudraprayag; (ii) in 1868, a landslide triggered upstream of Chamoli blocked the course of Alaknanda river; (iii) in 1893, a massive rock fall triggered near Gohna which blocked the course of Birahiganga river, a tributary of Alaknanda river; (iv) in 1968, the Rishiganga blocked due to a landslide near Rini village; (v) in 1970, Patalganga,

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a tributary of Alaknanda river blocked by landslide; (vi) in 1970, Alaknanda river blocked by a landslide near Hanuman Chatti; (vii) in 1978, the Kanauldia Gad blocked by a landslide in Uttarkashi; (viii) in 1998, Madhyamaheswar river, a tributary of Mandakini river blocked by a massive rock fall; (ix) in 1998, Malpa Gad, a tributary of Kali river blocked due to a massive rock fall in Kelash-Mansarovar pilgrimage route (Rautela and Pande, 2005; Pandey and Mishra 2015; Prakesh, 2015; Gulia, 2007; Thakur, 1996; Sah and Bist, 1998; Paul et al., 2000). Out of 9 landslide incidences, 5 reported incidences of river blockade are associated with the Alaknanda valley in Chamoli district.

Likewise, a huge amount of debris brought down by streams blocked at confluence of tributaries and narrow valley walls along the streams in the Uttarakhand region. These include (i) in 1893, Birahigang near its confluence with Alaknanda river blocked due to debris flows; (ii) in 1930, Alaknanda river blocked near Badrinath because debris flows; (iii) in 1970, Dhauliganga river blocked near Tapoban by the debris brought down by Dhak nala; (iv) in 1970, Alaknanda river blocked by the debris brought down by Karmanasa Nadi; (v) in 1979, Mandakini river blocked near Chandrapuri due to debris brought down by Kyunja Gad in Rudraprayag (Pandey and Mishra 2015; Prakesh, 2014; Gulia, 2007). Out of 5 incidences, 4 reported debris flow incidences of river blockade are associated with the Alaknanda valley in Garhwal region of Chamoli district.

Furthermore, some streams blocked because of moraines/glacial sediments and avalanches in the upper reaches of the Higher Himalayan region of Uttarakhand. These include (i) in 1957, Dhauliganga river blocked near Bhapkund by an avalanche coming from the Dronagiri river; (ii) in 1979, Alaknanda river blocked by avalanche near Bamni village in proximity of Badrinath; (iii) in 2002, Gandhwi river blocked by glacier sediments (Bisht et al., 2002; Bisht et al., 2011). All 3 reported avalanches and glacial sediments/moraines blockade incidences are associated with the Alaknanda valley in Chamoli district of Uttarakhand Himalaya.

Recently, a prolonged rock fall along with glacier avalanche took place in the upper reaches of the catchment of Raunthi Gadhera, a tributary of Rishiganga on February 7, 2021. Subsequent blockade and sudden breach of a huge volume of water saturated bouldary debris caused again blockade at confluence of the Raunthi Gadhera with Rishiganga. This caused reverse flowed of sediments leaden water along the Rishiganga upto 500 m and deposited a huge amount of debris over its course and is formed an artificial lake. This lake is around 500 m in length along the Rishiganga and around 100 m width across the same with an assumed depth of aound 20-40 m. In order to investigate the area to find out the causes and to overcome the threat form this lake in downstream.

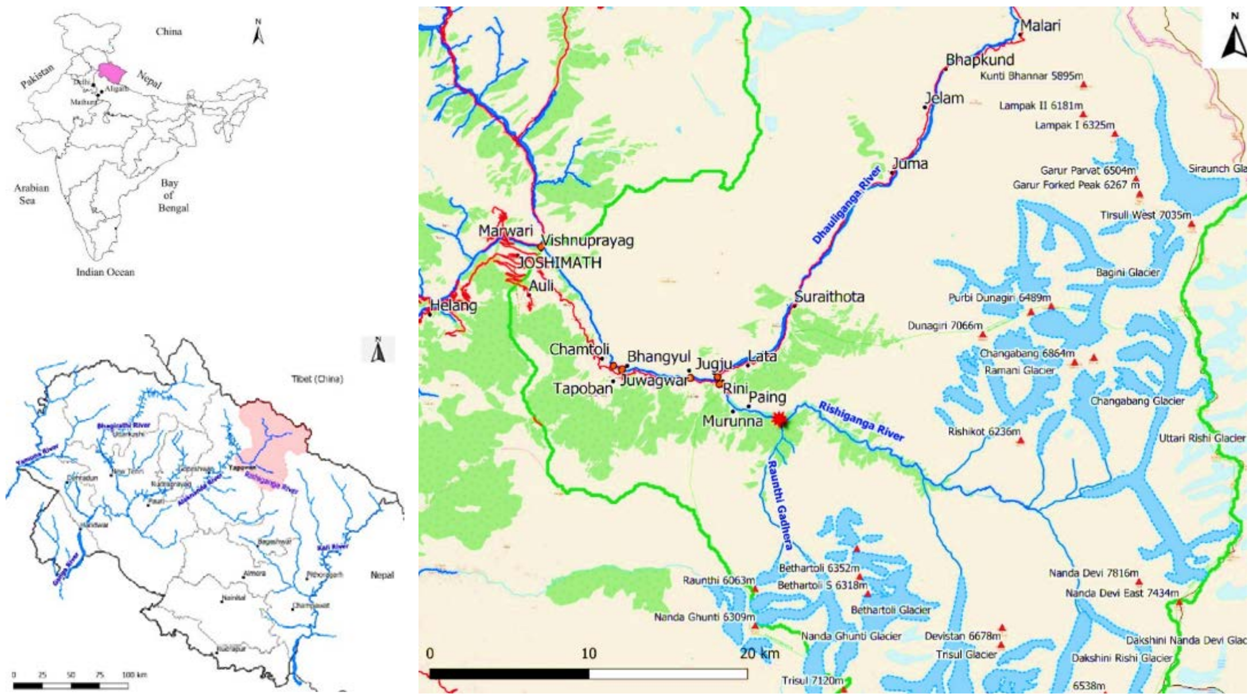

Figure 1. Map depicting the devastated area

2. The devastated area

Devastating flash flood of February 7, 2021 in Dhauliganga valley of Chamoli district in Indian subcontinent of Uttarakhand Himalaya however took place during the winter season. An artificial lake which formed over Rishiganga on the aftermath of initial flash flood incidence took place in the catchment of Raunthi Gadhera, a tributary of Rishiganga. The devastated area can be approached by Joshimath-Malari motor road till Rini village, at a distance of about 20 kilometers from Joshimath town and travel for around 10 kilometers to reach the confluence of Raunthi Gadhera with Rishiganga as well as damming site where at present exist lake over Rishiganga (Figure 1). Joshimath town is a famous tourist destination located in the Higher Himalaya and can be approached from Rishikesh by Rishikesh – Badrinath national highway (NH 58).

Meteorologically, it is observed that heavy concentrated precipitation events occur several places in this region every year not only during monsoon season, as pre monsoon also (Khanduri, 2020). This is mainly attributed to change in climate and rainfall pattern (Kumar et al., 2010; Praveen et al., 2020). Even though the region witnessed slight rainfall during the days preceding the incidence, winter rainfall in Uttarakhand had been below normal during 2020-21 (Table 1). However, the region experienced precipitation on February 4 and 5, 2021 and snow fall occurred in the high altitude region of Dauliganga valley. It is evident from the Tapoban and Auli which are located at an altitudes of 2000m asl and 2600m asl respectively. Between 6 and 7 February, 2021 Tapoban experienced 2.8°C and 5.4°C whereas Auli experienced 6.0°C and 9.6°C respectively in minimum and maximum temperature (Data Source: Uttarakhand State Disaster Management Authority).

Table 1. Avarage monthly rainfall in the area around the devastated region (Data source: Uttarakhand State Disaster Management Authority).

Place	**Rainfall (in mm)**				
	October 2020	**November 2020**	**December 2020**	**January 2021**	**February 2021 (till 13th)**
Tapoban	7.5	0	5	19.5	8.5
Auli	10	2	3.5	14	14.5

Figure 2. Washing away power house of Rishiganga hydropower project of 13.2 MW capacity upstream of Rini

Multipule intermittent damming and ensuing flash flood of Rishiganga and Dhauliganga river caused washed off a functional hydropower project of 13.2 Mw capacity on Rishiganga upstream of Rini (Figure 2) along with a RCC bridge of 60 m span over Rishiganga on Joshimath – Malari road at Rini in which disrupted connectivity for the people of 13 villages (Figure 3). To the downstream of this the floodwaters caused severe damage to another under construction hydropower project of 520 Mw of NTPC at Tapoban on Dhauliganga river (Figure 4). 204 people went missing, including 9 local people and 2 Police personnel, of these body of 83 persons could be recovered. Besides this heavy losses were incurred by public infrastructure and other properties.

Figure 3. Washed off motorable RCC bridge over Rishiganga on Joshimath – Malari State Highway at Rini

Figure 4. Severely damaged barrage of Tapoban-Vishnugad hydropower project with aggradation of river bed at Tapoban

3. Methodology

With the help of Handset Global Positioning System (GPS), taking the coordinates in and around the lake site. During the course of the fieldwork in the area devastated by flash flood geological observations were taken all along the Rishiganga valley with specific focus on an artificial lake which formed over Rishiganga at an elevation of 2389 m asl that falls in Survey of India toposheet numbers 53 N/13, 53 N/14 and 53 N/15. These toposheets on the scale of 1:50000 have been use to prepare the location map of the area using Geographical Information System (GIS) software (Arc Info 9.3).

4. Geomorphological and Geological set up

Initial flash flood incidence of February 7, 2021 occurred along the North flowing Raunthi Gadhera that originates from the glaciers of Nanda Ghungti (6309 m asl). It has confluence with Rishiganga to the East of Paing and Murunna villages and maintains a tectonically controlled NW-SE course that originates from the glaciers of Nanda Devi massif (Figure 5). It meets with Southwest flowing Dhauliganga river at Rini village that originates in the proximity of Niti pass. From Rini to Tapoban Dhauliganga river maintains a tectonically controlled E-W course and thereafter flows from NW-SE to meet Alaknanda river at Vishnuprayag.

Figure 5. Panoramic view of Nanda Devi massif (camera looking East of Rini)

The Rishiganga valley exhibits characteristically distinct rugged mountainous topography of the Higher Himalayan terrain. The imprints of geological structures and lithology are observed in the area in the form of strike ridges and deeply incised valleys. The area is observed to be dissected by several ridges and the ground elevations vary from about 1960 m asl at Rini to 7817 m asl at Nanda Devi massif which is second highest peak of the India.

Exposures of Higher Himalaya are thrusted over the rocks of Lesser Himalaya, along a Northerly dipping Main Central Thrust (MCT) passes across the Alaknanda river at Helang. Overlaying MCT, Helang, Joshimath, Suraithota and Bhapkund Formations which constitute medium to high grade metamorphic rocks. Helang Formation represents low to medium-grade rocks of greenschist facies while Joshimath, Suraithota and Bhapkund Formations constitute medium to high grade rocks of amphibolite facies are separated by Northeasterly dipping Vaikrita Thrust in this region, passing across the Dhauliganga river near Rini. (Heim and Gansser, 1939; Valdiya, 1980; Valdiya, 1989; Jain et. al., 2014).

At the confluence of Raunthi Gadhera with Rishiganga, mostly exposures of quartzites of Suraithota Formation are observed on the right bank of Raunthi Gadhera as well as both the banks of Rishiganga having with vertical cliff. These rocks are medium to course grained, greyish coloured, medium to thickly foliated and slightly to moderately weathered in nature. Rocks exposed in the area are generally observed to strike NW–SE with moderate dips towards NE. Other two prominent joints were observed to dip towards W and NW at steep angles (70º / 270º and 70°/310°) along with a vertical joints was observed to strike NE–SW (90°/70°).

5. Cause of damming Rishiganga

The flash flood incidence of February 7, 2021 was unexpected during winter season in which surprised everyone as also scientists of various domain across the worldwide. They made their sincere effort to reconstruct the sequence of this flash flood disaster. Based on the analysis of the satellite imageries, the huge rock mass sliding down from the long distance which generated energy that was held responsible for quickly melting snow and ice available in the area and fragmentation of detached landslide mass as well as glacial sediments initiating a debris flow that rushed downslope (Dave Petley, 2021; Shrestha et al., 2021; Shugar et al., 2021). Similarly, based on the field investigations carried out proximity of the affected area reveals that multiple intermitent damming added the discharge causing flash flood disaster situation occurred in downstream wherein massive damage and distruction have been taken place, perticularly in Rini and Tapoban (Rautela et al., 2021; Khanduri, 2021).

Figure 6. Rishiganga lake curved out channel from the center of the lake through which water is continuously draining out

According to villagers, they had heard sound of boulders falling in the early morning 0200 hours on February 7, 2021. On the basis of same, a prolonged rock fall along with glacier avalanche triggered over Raunthi Gadhera, a tributary of Rishiganga in the area which blocked the course of the same at an elevation of 3600 m asl. Subsequent breach resulting in a huge volume of water saturated bouldary debris gushing downstream. Key blocking at the confluence of Raunthi Gadhera with Rishiganga at an elevation of 2315 m asl by the same resulting in reverse flowed of water saturated debris along the Rishiganga up to 500 m. Increasing hydrostatic pressure, breaching of tomporary dam at confluence where released of water saturated debris with great force into downstream.

This reverse flowed of a huge volume of water saturated bouldary debris was deposited over Rishiganga and blocked the course of the same for 3 days between 9 and 11 February, 2021. This debris comprising of a mixture of ice blocks, rock fragments, morainic materials and boulders of quartzite, granitic gneiss and mica schist with silty-clayey matrix. The Rishiganga was curved out channel from the center of the lake through which water is continuously draining out on February 12, 2021 (Figure 6).

It is important to note that just upstream to confluence of Raunthi Gadhera and Rishiganga, occurrence of lacustrine deposits that consist a layers of sand and pebbles on the right bank of Raunthi Gadhera which was indicating evidence of paleo lake in the same region. These deposits has now been mostly eroded in the flash flood of Raunthi Gadhera (Figure 7).

6. Results and discussion

Over the past decades, the Alankanda river and its tributaries like Dhauliganga, Rishiganga, Patalganga and Birahiganga had been blocked due to rock fall, debris slide, debris flow, avalanche and glacial sediments and subsequent breach caused devastation in downstream. These inflicted heavy loss of life and property together with other infrastructure and natural resources. Total of 12 reported incidences of blockade are associated with Alaknanda valley in Chamoli district of Uttarakhand. It is noteworthy that besides Patalganga and Birahiganga blockade in the Lesser Himalayan terrain, most of the damming of streams concentrated in Higher Himalayan terrain, particularly to the North of Main Central Thrust (MCT). This is however attributed to the geomorphology and geology. It was observed that most of the damming of streams because of (i) confluence of tributaries; (2) narrow valley; (iii) Thrust/Fault and folded strata; and (iv) physical and chemical weathering in rocks. It was observed that most of the dam breached during the monsoon season.

Figure 7. Evidence of paleo lake showing lacustrine sediments on the right bank of Raunthi Gadhera near its confluence with Rishiganga

Initial flash flood took place in Raunthi Gadhera, a tributary of Rishiganga on February 7, 2021 in the early morning at 1015 hours. Blockade of Raunthi Gadhera by prolonged rock fall and subsequent breaching caused a huge amount of water saturated bouldary debris gushing downstream. At the confluence of Raunthi Gadhera and Rishiganga, flooded water saturated bouldary debris of Raunthi Gadhera directly hit the valley wall and damming the same place for a while in which back flowed of sediments leaden discharge along the course of Rishiganga upto 500 m.

Continuously increasing hydrostatic pressure, temporary dam at confluence was breached, a huge debris mass along with boulders and ice was dumped over the course of the Rishiganga, left behind this sediments barier water accumulated and formed an artificial lake. Between 9 and 11 February, 2021 the course of Rishiganga was permanently blocked by the debris brought down by the Raunthi Gadhera. The Rishiganga was curved out channel from the center of the lake through which water is continuously draining out on February 12, 2021. As directed to personnel of ITBP and SDRF, physically widen the channel and cleared of obstructions of logs (Figure 8). The channel was thus widened upto 20 m between February 22 and March 2, 2021 to ensure proper draining out water from the lake.

The flooded water of Rishiganga resulted in swiping away of an operational hydropower project of 13.2 Mw capacity on Rishiganga upstream of Rini and severe damage to another under construction hydropower project of 520 Mw of NTPC at Tapoban on Dhauliganga river. As many as 204 persons went missing, of these 83 bodies could be recovered while 12 persons injured and 360 farm animals were lost in the flash flood incidence together with another property and infrastructures.

7. Conclusions

Evolutionary history, geotectonic set up, geomorphology and hydrometeorological characteristic make the hilly region of Uttarakhand prone to a number of natural hazards like rock fall, debris flow, flash flood, flood, avalanche etc. Apart from these the region has witnessed earthquake several times because of the same region falls in earthquake zone IV and V according to earthquake zonation map of Uttarakhand (IS, 1893) where the devastated area lies in seismic Zone V. Change in rainfall pattern along with climatic variability because of global warming due to which concentrated heavy rainfall and cloudburst incidences are frequently occur in the area. This region has a long history of disasters due to which thousands of fatalities while tremendous property and infrastructure losses were occurred. The same region has also witnessed a number of natural dams formed by these natural hazards. Subsequent breach caused enormous loss of life, property, infrastructure in downstream.

Figure 8. Personnel of ITBP and SDRF widen the channel and cleared of obstructions of logs

Based on the investigations in the area around lake site, it is suggested that initial flash flood took place in Raunthi Gadhera on the aftermath of landslide dam breached. Another key damming of streams was observed at confluence of the Raunthi Gadhera with Rishiganga. Occurrence of lacustrine deposits that consist a layers of sand and pebbles on the right bank of Raunthi Gadhera just upstream of confluence point which was indicating evidence of paleo lake in the same region.

The lake formed over Rishiganga on the aftermath of initial flash flood in February 7, 2021 that is needs detailed geomorphological evaluation. Because of the muddy debris barrier as this is problematic during monsoon when Rishiganga will contribute significant discharge. This will create hydrostatic pressure and the possibility of breaching of the same cannot be ruled out. In view of vulnerability to flash flood again in the downstream by the same, estimating regular discharge and installing early warning system for flood forecast in downstream. Apart from regular monitoring of the lake should be done by state-of-art techniques.

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