Uttarakhand Flash Floods February 2021: Perils of Under-Preparedness or Disregard for the Environment or Both

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Abstract
Disaster hit Uttarakhand's Chamoli district on February 7, 2021, in the form of sudden flash floods after a portion of the Nanda Devi glacier was broke apart. The sudden floods were reported in the intricately linked tributaries of the Ganga River - Dhauli Ganga, Rishi Ganga, and Alaknanda rivers which triggered widespread panic and large-scale devastation and fatalities.
The Flash floods damaged two power projects - NTPC's Tapovan-Vishnugad Hydel Project and the Rishiganga Hydel Project, five bridges, roads, and settlements, in and around Raini, Tapovan and Joshimath areas in Uttarakhand. Scores of laborers working at the sites of the Hydel Projects were trapped and feared to have lost lives, despite all our efforts to rescue them. It is the second large-scale tragedy in the same area within a span of fewer than eight years. Questions are being asked,"Why did we not learn any lesson from the earlier disaster in the very same area"? Was it under-preparedness, or was its disregard to the environment or both? This paper attempts to find the right answers to the questions and suggest solutions so that in the future, such avoidable disasters do not happen.

Keywords: Cryosphere, Paraglacial, Discharge-balance, Risk-evaluation, Flash floods, Avoidable-causalities, Heat-trapping Greenhouse, NDRF.

Himalayan Geoenvironmental and Vulnerability

The Himalayas are young mountains but consists of a tectonically active orogenic system, formed as a result of a massive collision between Eurasian and the northward drifting Indian plate about 50 million years ago. It encompasses the northern frontiers of India. The Hindukush-Karakoram Himalaya hosts the largest glacier system and is commonly referred to as the third pole of the earth. The Himalayan Mountain range is subdivided into four principal tectonic zones, from south to north these are: (a) the Sub-Himalaya Shiwalik Range, (b) the Lesser Himalayan, (c) the Higher Himalayan Crystalline, complex and (d) the Tethyan Himalayan. The changing climate has resulted in the depletion of the hill aquifer system in the region. With rapid climate change and fragile mountain cryosphere and landscapes are evolving, and new threats of landslides, Glacial Lake Outburst Floods (GLOFs), avalanches, and flash floods are emerging at a very fast pace posing a serious risk to the vulnerable Indian Himalayan Region (IHR).

Causes For Uttarakhand Galcier Outburst and Flash Floods

The flash floods were initiated on 7th February 2021 in the vicinity of the Nanda Devi National Park, a UNESCO World Heritage Site4 in the outer Garhwal Himalayas in Uttarakhand state, India. It is assumed to be caused by a landslide, an avalanche, or a glacial lake outburst flood (GLOF).6 It resulted in floods in the Chamoli district, most notably in the Rishiganga river, the Dhauliganga river, and in turn the Alaknanda - the major headstream of the Ganges (Figure 1).

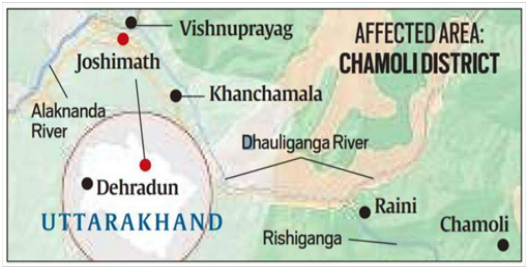

Figure 1: Figure showing the Affected Areas by the Flood

Scientists are still trying to unravel the reasons for the flash floods. There are three possible causes that may have triggered the flash floods in Uttarakhand.

1. **One Possible Cause was the Sudden Break of a Glacier High in the Mountains**: Reports immediately after the the disaster proposed that the floodwater was triggered by the sudden overflow of a glacial lake in the mountain high up, known as a glacial lake outburst flood (GLOF).9According to some reports, the flooding may have been caused by a portion of the Nanda Devi glacier breaking off early on 7th February, releasing the water trapped behind the ice and causing a glacial lake outburst flood.

Anjal Prakash, the Research Director of the Bharti Institute of Public Policy at the Indian School of Business in Hyderabad, indicated that it was too early to find the exact reason behind this disaster. He also stated that satellite images showed that a section of a glacier broke off, but how that can be related to the successive floods is still not known. One possible reason could be that the glacier was holding a lake of meltwater, and the heavy snowfall in that region two days earlier might have added plenty of volume to the lake that the water forced its way out, breaking the glacier and gushing into nearby rivers.

2. **Triggering a Landslide:** Other reports have suggested that satellite images imply that a landslide may have triggered the events. On 8 February 2021, The Times, London, reported that a flood was caused by a portion of the glacier being torn away and causing a landslide. In satellite images, a 0.5 mi (0.80 km) scar is visible on Nanda Ghunti, a 20,700 ft (6,300 m) peak on the southwestern rim of the Nanda Devi sanctuary, a wall of mountains surrounding the Nanda Devi massif.13 According to an article in Scientific American, 12 February 2021, data from Planet Labs was interpreted by Dan Shugar, a Geomorphologist at the University of Calgary, and suggested that roughly six hours after the floods, the latest Planet Labs satellite images discovered a trail of dust and a dark scar on the pearl-white peaks above the flood zone—clear signs of a landslide. It was noticed that a hanging glacier of enormous size, roughly 15 football fields long and five across, had broken from the steep face and plummeted downward, bringing down some of the rock faces with it. Shugar says this ice and rock avalanche crashed into the Ronti Gad, a smaller tributary that feeds into the Rishiganga and then Dhauliganga rivers.

According to BBC News, five scientists from the Wadia Institute of Himalayan Geology, Dehradun, India, flew over the site in a helicopter, took photographs, and gathered other data; they consider the hanging glacier that cracked and plunged into the Rishiganga basin to have been attached to a subsidiary peak, Raunthi, 5,600m (18,372ft), just below Nanda Ghunti.

Geomorphological observations in their report said that a pre-and post-change analysis from the satellite imagery has shown that a large rockslide may have occurred along the western slope of the Trishul glacier. Analysis of pre-event imagery from the Sentine l-2 satellite (dated 5th of February, 2021) shows an overhanging rock formation with the existing crack on the flank of the western peak adjacent to the Trishul glacier. This may have resulted in the formation of ice and rock-laden

unstable block upslope. On 7th February, this block of ice and rocks probably collapsed due to snow melting and consequent percolation of meltwater into the cracks/joints, resulting in a translational failure. The entrained ice melted rapidly as the landslide moved northwards along the Rishiganga valley, thus resulting in a huge surge of water, eventually turning westward into the Dhauliganga valley, causing massive damage (Figure 2).

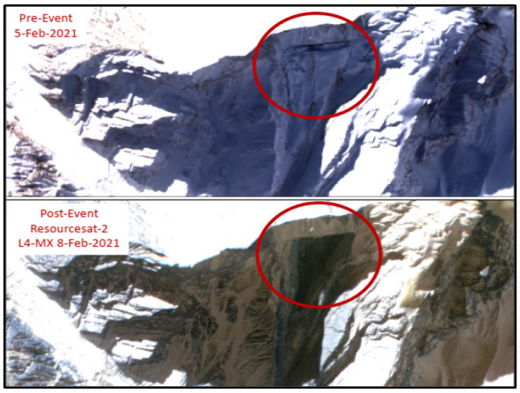

Figure 2: Satellite Images Depicting Probable Rockslide in Trishul Glacier

3. **Climate Change Effect:** Climate change and the shifting weather patterns caused by global warming have been cited as another reason. The thermal profile of ice is increasing, as earlier the temperature of ice ranged from -6 to -20 degrees Celsius, it is now -2 degrees, making it more susceptible to melting. Climate change-driven unpredictable weather patterns such as increased snowfall increased rainfall, and warmer winters have led to the melting point of an enormous amount of snow.

According to Dr. KalachandSain, Director of the Wadia Institute of Himalayan Studies, Dehradun, climate change was the major factor in the rapid freezing and thawing of ice that caused glacier fractures. He mentioned that the rapid temperature changes led to freezing and thawing of ice and glacial fractures over time. Glaciers collect snow in winter and lose them in summer due to melting. But as temperatures rise, glaciers lose ice faster than they can collect it. Ice melting is known as the retreat of glaciers.

Anjal Prakash also stated that the region, including the Hindu Kush Himalayan Mountains and the Tibetan Plateau, "has been a hot spot due to climate change for a noticeable long time." The region is often called Earth's third pole because the storage of ice and snow in the Himalayan watershed accounts for the largest reserves of fresh water outside of the Polar Regions. This area is the foundation of 10 major river systems from where water is provided to almost 2 billion people.

Reports on climate change reports have already cautioned that global warming is not only a threat to this water supply but also increases the probability of other natural threats. In the Intergovernmental Panel on Climate Change's 2019 special report on oceans and the cryosphere, scientists illustrated that the glacier retreat and melting and thawing of snow are making mountain slopes more insecure and unstable and also leading to an increase in the number of glacial lakes, further increasing the possibility of a sudden, catastrophic events.

4. **Most Plausible Cause - "An Extraordinary Rock and Ice Avalanche and Debris Flow":** After months of debate behind the cause of this disaster, a team of 53 International Scientists from the Universities of Colorado, Washington, Zurich, Potsdam, Utah, Toulouse, Heidelberg, Geneva, Newcastle, Oslo, and Utrecht, has confirmed "an extraordinary rock and ice avalanche and debris flow" as the most likely cause that led to the Uttarakhand floods in February 2021. The team used computer modeling to reconstruct "in almost real-time" how the flood unfolded. High-resolution Google Earth data suggested that a bigger hanging glacier of the rock-ice mass collapsed from Ronti peak, leaving a substantial chunk vulnerable and issued a warning that it could happen again.

Dan Shugar said no evidence of any changes at Nanda Devi and Nanda Ghunti glaciers before the flood. Seismic data from two stations indicated that around 10:21 am, a 20 million m3-mass of rock (80%) and ice (20%) broke off from an altitude of 5,500m above the sea level, and the frictional heat generated nearly melted off the ice during the descent.

Rapid Damage Assessment

Rapid damage assessment was carried out of the affected areas using high-resolution satellite images. Indian Cartosat-2S images show damages at NTPC Power Project at Tapovan (Figure 3& 4). Table 2 shows the details of lives lost and damage/loss to infrastructure.

Figure 3: Satellite Images showing Damages to (1) Power Project, (2) Bridge

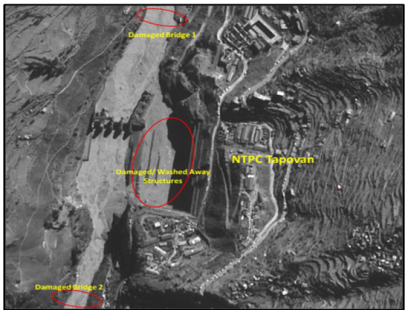

Figure 4: Satellite images showing Damages at NTPC, Tapovan

Table 1: Data of Affected lives as well as Damage and Destruction of the Property

Lives Affected	a) People affected: > 550 b) 39 people died +34 trapped in Tapovan Tunnel who presumably died as they could not be rescued = 73 c) Injured: 6 d) Missing: 168 (from Tapovan Ritwik Coy, Kericho, Rishiganga Coy, Om Metals, HCC, Tapovan, Raini, and Ringi Villages)
Destruction	a) More than 150 boats perished b) 5 Bridges washed away(1 BRO, 1 NTPC, 1 PR, and 2 PWD) c) 4 Projects damaged (2 Rishiganga projects, Tapovan Dhauli Ganga project, BRO project) d) Damages to BRO Laborcamp and in Reini Village

Response and Recovery

The response and rescue forces activated by the Uttarakhand State and Central Governments were as follows:

- Indo-Tibetan Border Police (ITBP) –425.
- State Disaster Response Force from Haridwar (SDRF)–70.
- National Disaster Response Force from Dehradun and Ghaziabad(NDRF)–129.
- State Health Department - 2 Medical Teams and 6 Ambulances
- Army personnel – 124.
- 3 Army Aviation Helicopters
- Heavy Machinery likes Dozers, Excavators, JCBs, and special machines for drilling by BRO, PWD, and Private Companies working on the project.

Many villages falling in the affected zone were earlier evacuated as authorities released water from two downstream dams along the river to stop the floodwaters from reaching Haridwar and Rishikesh. Two C-130J Super Hercules aircraft, with three teams of the National Disaster Response Force (NDRF), were flown from Delhi and deployed for the rescue mission. According to the Director-General of the NDRF, the rescue work would be under process for at least two days. Emergency crews managed to rescue 16 workers who had been trapped inside one of the smaller tunnels. Another 35 to 40 workers reportedly trapped 5 km downstream in a second tunnel at the Tapovan Vishnugad Hydropower Project site built by the NTPC could not be rescued due to the unavailability of proper machinery and the amount of slush in the tunnel.

Challenges Posed

Hydro Power Projects in Dangerous Zone: According to The New York Times, scientists have repeatedly been warning the Government of India for many years that the Himalayan mountains are melting at a dangerously high rate due to global warming and that area's fragile and sensitive ecosystem is continuously becoming physically exposed to the dangers of development projects. Dr. Ravi Chopra, the Director of the People's Science Institute in Uttarakhand and a member of a scientific committee, appointed by India's Supreme Court in 2014, had opined against building dams in the fragile glacial zone, i.e., river valleys where the floor is higher than 7,000 feet. Still, the Government of India/State Governments disregarded the objections. According to Dr. Chopra, both the hydroelectric power projects that were washed away in the floods were constructed in the prohibited zone. The headman of Reni village stated that residents of the village were already apprehensive that the blasting of the rocks during the hydropower dam's construction would result in hazardous landslides.

Climate Change Adaptation: Another major concern that requires immediate attention is continued environmental disregard and climate crisis. A holistic approach is needed for battling climate change through mitigation measures to decrease the movement of heat-trapping greenhouse gases into the atmosphere and adapt ourselves for the expected future climatic changes and their impact. Owing to this climactic crisis of global warming, glaciers are continuously shrinking, leading to the formation of a large number of lakes all across the Himalayas that have the potential to cause dangerous flash floods in the event of a breach. Experts are predicting that by 2070 there will be melting away of 70% of small glaciers and disappearance of 45% of medium and large glaciers. Mitigation measures to deal with this challenge are constructing channels for gradual and controlled discharge of water from glacial lakes that will ease the pressure on them and minimize the likelihood of a breach. Containment of glaciers with solid local material is another option that s has been successfully experimented with and applied in Sikkim.

Insufficiency of Preparedness: Till the setting up of the High Powered Committee (HPC) in August 1999 by the Government of India, the disaster management concept was response-oriented. Nodal Ministry for managing disasters was Agriculture, as it was presumed that India faced either floods or drought every year. Earthquakes and cyclones were once in 5-6 years happening, which could be managed with relief. We had Relief Commissioners at the State and Centre level. There was no Secretary of Disaster Management to look after the mitigation and preparedness aspects. One of the major recommendations of the HPC was to change the response-centric concept to a holistic approach with an emphasis on pre-disaster phases of prevention, mitigation, and preparedness. The nodal Ministry for Disaster Management was also changed to the Ministry of Home Affairs in 2002. HPC also recommended the formulation of a framework on Disaster Management at Central, State, and District levels, culminating in the enactment of the Disaster Management Act 2005. Sections 23, 31, and 32 of the Disaster Management Act, 2005 envisage that all States, districts, municipal corporations, local bodies, other departments, and Institutions would have a Disaster Management Plan (DMP), which may be implemented during actual disasters and mock exercises.

It is informed that most of the SDMAs, DDMAs and other Departments/ Institutions have developed their Disaster Management plans, but they are hardly referred to during actual disasters. The reasons being that these plans have been made by experts, and the stakeholders were not involved in their preparation, and hence they do not have much clue on how to react and with which force, and how to marshal appropriate resources. These plans are also not updated regularly after every disaster and after yearly mock exercises. Incident Response System is hardly followed during actual disasters or mock exercises.

Lessons Learnt and Recommendations

Uttarakhand is home to the fragile Himalayan Mountains and has encountered a chain of natural disasters over the last few decades. Since 1990, Uttarakhand has experienced two major earthquakes of magnitude greater than six Richter scale, which

was Uttarkashi in 1991 and Chamoli in 1999. There has been a history of frequent landslides/ cloud bursts/ flood disasters too. Malpa (1998), Okhimath (1998), Fata (2001), Gona (2001), Khet Gaon (2002), Budhakedar (2002), Bhatwari (2002), Uttarkashi (2003), Amparav (2004), Lambagar (2004), Govindghat (2005), Agastyamuni (2005) and Ramolsari (2005) are a few natural disasters to bring to the notice.

Uttarakhand Tsunami -In June 2013, Uttarakhand underwent one of its most catastrophic natural disasters, which claimed the lives of thousands of people and animals. As per the records, about 6,000 people were killed, found missing or presumed dead, 4,200 villages were affected, 9,200 cattle/livestock were lost, and 3,320 houses were fully damaged. The floods led to 170,000 tourists and local inhabitants stuck in the mountain, later salvaged in the rescue operations. This was also known as Uttarakhand Tsunami.

However, there has been a noteworthy decline in causalities and damage during Uttarakhand Tragedy 2021 compared to the Uttarakhand Tsunami of 2013, which signifies that our level of preparedness and response has improved and it delivered. But still, there are gaps that need to be plugged in to save lives and the loss of infrastructure. New Technologies and innovative ways to mitigate disasters need to be adopted to bring in "Zero Tolerance to Avoidable Casualties, Loss of Infrastructure and Degradation of the Environment."Some recommendations are given in the following paragraphs under specific subheadings of areas of gaps and pitfalls.

Non-Monitoring of Glaciers

Present Scenario: Just relying only on satellites and remote sensing is not going to be sufficient enough.

Recommendations

- The paramount step in confronting the threat from these glacial lakes is to start monitoring the glaciers more actively & regularly.
- Very close measurement of the bathymetric changes, the mechanisms of expansion, changes in water levels, discharge balance, mass balance, and other attributes is necessary.

Inadequate Early Warning System

Present Scenario: We are lacking in building an efficient warning mechanism for glacial outbursts, flash floods, and extreme weather in the Himalayan region.

- The NTPC Visnugad-Tapovan Hydropower project, which was destroyed due to flash floods and suffered casualties with several workers who went missing, did not have any early warning system.
- Unfortunately, none of the 65 projects operating in the Himalayas have any early warning system.

Recommendations

- There is an urgent need for an efficient early warning system and alarm system to be set up at the glaciers and lakes, which will warn the community downstream whenever an overflow happens. It is important to let the people evacuate before a disaster strike by timely early warning. This is called last-mile connectivity for timely evacuation.
- Sensors can be placed at pre-selected places in the glaciers, warning of any outflow of water. The mix of workforce and technology and last-mile connectivity would help timely early warning for people to evacuate.
- There should be base stations or command centers for continuous monitoring of signals received from sensors placed at glaciers. If any disturbances in the signals are noted, they should timely communicate the information to District Magistrates/ or Gram Panchayats Head/ or Tehsildars at each District and village level. Further, they should disseminate information to the General Public to evacuate the place well before the time.

Delayed Incidence Response System (IRS) and Insufficient Capacity Building

Present Scenario: We lack the following Unified Command System for managing disasters in which multiple response institutions/organizations are involved. Hence optimum utilization of the resources mobilization and deployment is not done, which leads to the duplicity of efforts and sometimes clash of egos among the commanders of response

teams. IRS, which has been formulated with great efforts, is not used at State and District levels. At the community level, people who are the first responders in any disaster are not aware of the risks they are facing. Hence, adequate capacity is not built at the local level, nor are they adequately equipped with resources.

Recommendations

- Development of Disaster Management Plans at District level and below for all the entities, like schools, colleges, universities, cinema halls, hospitals, hotels, office complexes, RWAs, local bodies, panchayats, village level, by the stake-holders themselves with some help from the qualified Disaster Management experts. The stakeholders should own the document.
- DDMA should share district DM plan among all Emergency Support Functionaries (ESFs).
- Capacity building of the community to manage the impact of the disaster, especially in the initial phases of disaster, should be strengthened. Identify, train, and keep active through regular mock drills at least 1% population as volunteers.
- One battalion of NDRF in Dehradun/ Haridwar should be placed. The State should raise at least one SDRF battalion and place its companies in the most vulnerable districts. At the district level, civil defense teams should be raised and become the response teams of the District Collector. At the village level, volunteers should be trained to save lives by timely rescue and minimum relief during the disaster.
- New Technologies and modern machinery or equipment should be designed/innovated to rescue and evacuate the people trapped inside the tunnels or stuck in the confined places. Now we do not have such equipment or machines, and because of this, we lost 30-40 people in this disaster who could have been saved.
- People working at Hydel power plants or widening roads should have a rescue plan and should be trained enough and equipped to rescue themselves if trapped. Mock exercises should be carried to practice quick evacuation and different routes to follow.
- Every village should have a helipad within its premises or nearby. Helipads should also be developed on flat areas. It will surely fasten the rescue, evacuation, and relief operations and facilitate better casualty management.
- Accounting and proper records of pilgrims/ tourists are entering various areas of importance, like Char-Dam Yatra and adventure areas. Maximum footfall in the various shrines in Uttarakhand should be calculated, and registration of tourists done at each location like it is being done for Amarnath Yatra and Mata Vaishnodevi and Tirupati Shrines. This will help in the identification and informing disaster response teams in case of any disaster.
- At every pilgrim and tourist site, there should be a proper plan ready to manage any disaster situation, for example, alert messages, alarm systems, evacuation plans, and routes with proper signage at a place for directing the people. The people working at these sites should be fully trained to manage such situations, and periodic mock drills and training should be undertaken.

Unplanned Development and Construction

Present Scenario

- Continued developments of Hydropower projects have been playing a devastating role in turning hazards into disasters. Supreme Court of India observation on Civil Appeal 6763 in 2013, "Development of new hydropower projects in that eco-fragile region will have extensive repercussions on ecology and environment of Alakhnanda and Bhagirathi river basins."
- Supreme Court of India had directed the Ministry of Environment, Forest and Climate Change (MoEFCC) to constitute an expert body and make a detailed report of whether existing and under construction hydropower projects have contributed to environmental degradation and to what extent they contributed to the 2013 Uttarakhand tragedy. Based on the report, Central Government in 2019 banned the construction of new power projects in the Ganga valley.
- Despite the above legislation and directions by the Supreme Court of India, numerous hydropower projects are getting clearances and sanctions for the construction in the hazard-prone zone.
- Illegal muck disposal in rivers has often

been called out as one of the main culprits in increasing the occurrence of disasters like floods in Uttarakhand, as it raises the riverbed level.

Recommendations

- Supreme Court directions should be strictly complied with, and exemplary punishment under IPC should be given to defaulters.
- Risk evaluation of already functional hydropower plants should be carried out, and necessary precautionary steps must be taken, ensured, and monitored.
- No new hydropower projects should come up in the Ganga valley and other vulnerable areas.
- Roads should be constructed at higher places rather than next to the rivers.
- Widening of roads should not be done by explosives and blasting as they create disturbance to fragile young mountains and lead to landslides. Hence, modern machinery should be used for road widening without using explosives that will cause minimum impact to the surrounding areas.
- Identify suitable sites at least 500 meters away from the river banks for disposal of muck and excavated material.
- Besides carrying out the environmental impact assessment (EIA), disaster impact assessment (DIA) should also be mandatory for major projects.
- Removal/ relocation of all the habitation, including ashrams at least 500 yards from the rivers.
- New constructions must follow NBC 2019 provisions.
- Identify vulnerable and weak buildings through rapid identification methods.
- Incentives to be given by way of income tax relief for retrofitting the buildings to make them earthquake resistant.

Conclusion

Uttarakhand Flash Flood Feb 2021 reminds the Authorities and the communities that flash floods and landslides would continue to happen if we do not identify the existing risks, prioritize them and take remedial measures. In gist they are, regulate the entry of pilgrims and tourists in Uttarakhand, no more electric power projects, widening of roads with latest machines and minimal blasting, removal of hotels/residential buildings/ashrams within 500 yards of the River Ganga, especially near Rishikesh, Haridwar, Rudraprayag, and other small towns and villages, making roads along higher heights rather than next to rivers and no dumping of debris including construction material inside the rivers. On the plus side, we can say that we have an adequate and quick response system.

References

Banerjee, Biswajeet, and Rishabh R. Jain. "Glacier Breaks in India's North; Flood kills 9, 140 Missing." *Claims Journal*, 2021.

Banerjee, Biswajeet, and Rishabh R. Jain. "Rescuers in India Digging for 37 Trapped in Glacier Flood." *US News*, 2021.

Banerjee, Chandrima. "Rock-ice Avalanche led to Chamoli Floods: Study." *The Times of India*, 2021.

Biswas, Soutik. 'Hanging' Glacier Broke Off to Trigger India Flood." *BBC*, 2021.

"Centre will Extend all Possible Help to U'khand Govt to Tackle Flood Situation, says Amit Shah." *Lokmat*, 2021.

Dewey, John F., and John M. Bird. "Mountain Belts and New Global Tectonics." *Journal of Geophysical Research*, vol. 75, no. 14, 1970.

Dewey, John F., and Kevin Burke. "Tibetan, Variscan and Precambrian Basement Reactivation: Products of Continental Collision." *Journal of Geology*, vol. 81, no. 6, 1973, pp. 683-692.

Harper, Kelso. "Miniature Satellites Reveal Cause of Deadly Uttarakhand Flood that Devastated Dams." *Scientific American*, 2021.

Liu, Jia, et al. "Increase in Occurrence of Large Glacier-related Landslides in the High Mountains of Asia." *Scientific Reports*, vol. 11, 2021.

Mashal, Mujib, and Hari Kumar. "Before Himalayan Flood, India Ignored Warnings of Development Risks." *The New York Times*, 2021.

"Many Die, Hundreds Missing as Himalayan Glacier Bursts in India." *Aljazeera,* 2021.

"Nanda Devi and Valley of Flowers National Parks."

UNESCO, https://whc.unesco.org/en/list/335

Patriat, Philippe, and Jose Achache. "India-Eurasia Collision Chronology has Implications for Crustal Shortening and driving Mechanism of Plates." *Nature,* vol. 311, 1984, pp. 615-621.

Ramesh, Sandhya. "Uttarakhand Disaster likely caused by Landslide, not Glacial Outburst, Satellite images Reveal." *The Print*, 2021.

Tomlinson, Hugh, and Bilal Kuchay. "Himalaya Disaster in Uttarakhand Exposes Risks of India's Rush for Green Energy." *The Times*, 2021.

Verma, Lalmani, and Deeptiman Tiwary. "Uttarakhand Flood Wreaks Death, Damage." *The Indian Express*, 2021.

Wester, Philippus, et al. *The Hindu Kush Himalaya Assessment*: *Mountains, Climate Change, Sustainability and People*. International Centre for Integrated Mountain Development and Springer, 2019.

"Uttarakhand Glacier Burst: Dozens Missing after India Dam Collapses." *BBC News*, 2021.

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