

**BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL  
PRINCIPAL BENCH AT NEW DELHI  
ORIGINAL APPLICATION NO. 720 OF 2023**

**IN THE MATTER OF:**

On the news item appearing in Current Science dated 25.10.2023 titled "Need to declare the Higher Himalaya an eco-sensitive zone"

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Filed by

*Avneesh*

Place: New Delhi  
Dated : 01.04.2024

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**Joint Committee Report**  
**in the matter of original Application No. 720/2023**

On the news item appearing in Current Science dated 25.10.2023 titled  
“Need to declare the Higher Himalaya an eco-sensitive zone”

Hon'ble NGT vide its Order dated 18/12/2023 in the matter of Original Application No. 720/2023 instructed the following: -

“.....3. *The facts disclosed in the report, in our view, do give rise to a substantial question relating to environment due to implementation of Scheduled Enactments under NGT Act, 2010 and the facts discussed in the report, if correct, shows very serious situation of the area concerned which requires immediate attention and appropriate action, preventive, remedial and protective. However, before taking any further action in the matter, we find it appropriate to call for a factual report by constituting a joint Committee comprising:-*

- i. A senior representative of Ministry of Environment, Forest and Climate Change (hereinafter referred to as 'MoEF&CC')*
- ii. An Expert nominated by Director, GB Pant Institute of Himalayan Studies, Pant Nagar*
- iii. A Professor nominated by the Director, IIT Roorkee (Expert in the field of Civil Engineering).*

- 4. We make it clear that, in case, MoEF&CC finds it necessary to engage any other Expert in the Committee, it may do so by nominating such authority.*
- 5. MoEF&CC shall be the nodal agency for coordination and compliance.*
- 6. The said Committee shall examine the matter, if necessary, visit the site concerned, collect relevant information, study the matter and submit a detailed factual report with all relevant materials within three months by e-mail at judicial-ngt@gov.in preferably in the form of searchable PDF/ OCR Support PDF and not in the form of Image PDF.*
- 7. A copy of this order be forwarded to a senior representative of MoEF&CC, Expert nominated by Director, GB Pant Institute of Himalayan Studies and Professor nominated by the Director, IIT Roorkee by e-mail for compliance.*
- 8. List this matter on 02.04.2024.”*



In compliance of the order dated 18/12/2023 of the Hon'ble National Green Tribunal (NGT), in the matter of original Application No. 720/2023, the Ministry of Environment, Forest and Climate Change, has constituted the Joint Committee vide Office Memorandum dated 26/02/2024, as:

- i. Director, GB Pant National Institute of Himalayan Environment, Almora, Uttarakhand (overall coordination).
- ii. DDG or his representative, Regional office, MoEF&CC, Dehradun, Uttarakhand.
- iii. A Professor nominated by the Director, IIT, Roorkee (expert in Civil Engg.).
- iv. A representative of Director, IIRS, Dehradun.
- v. A representative of Director, Wadia Institute of Himalayan Geology, Dehradun.

As per the nominations received from the above mentioned institutions, the following members have been nominated to represent the Joint Committee for examination and submission of a factual report on the item published in 'Current Science' Volume 125 number 8, dated 25.10.2023 on 'Need to declare the Himalaya an Eco-Sensitive Zone'.

Name and Designation	Address	Mobile (M) and Email (E)
Dr. K. Chandra Sekar Scientist – F & Regional Centre Head	Garhwal Regional Centre, G.B. Pant National Institute of Himalayan Environment, Srinagar Garhwal - 246174	M: 9410344484 E: kcsekar@gbpihed.nic.in, kcsekar1312@rediffmail.com
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The Terms of Reference of the Joint Committee are as under:

- i. To examine the Item published in Volume 125 Number 8, dated 25.10.2023 in 'Current Science' on 'Need to declare the Higher Himalaya an Eco-sensitive Zone' and based on other relevant information / material collected on the subject and submit a factual report to the Ministry of Environment, Forest and Climate Change, New Delhi for onward transmission to the Hon'ble NGT, Principal Bench
- ii. To examine various regulations under the Wildlife (Protection) Act, 1972, Forest (Conservation) Act, 1980 and Environment (Protection) Act, 1986, in place in the proposed area where formulation of eco-fragile area is suggested in the article and recommend appropriately.
- iii. The Joint Committee may co-opt any other experts to assist in examination and preparation of its factual report.
- iv. The Joint Committee shall be coordinated by the Regional Office (RO), Dehradun and to this effect RO, Dehradun may nominate a dedicated Officer to assist the Committee.

As directed by MoEF&CC vide letter No. 11/14/2023-ESZ dated 26/02/2024, G.B. Pant National Institute of Himalayan Environment and MoEF&CC, RO Dehradun has held the first meeting of the committee on 14/03/2024 through video conference. The second meeting of the committee was held on 22/03/2024 and the third meeting was on 26/03/2024. Minutes of the meetings are enclosed as Annexure I, II and III.

During the above-mentioned meetings the Joint Committee discussed various aspects of geology, hydrology and ecology of the area of interest, reviewed several published literatures and data available with the institutions. The Joint Committee has extensively worked on the data available in RS & GIS domain and prepared a number of maps. The joint committee also explored on the areas which are already protected under different Protected Areas and Eco-Sensitive Zones through remote sensing.

The members of the committee opined that a short field visit needs to be conducted in the month of April to collect the representative data on sediment load in the area of interest and verify the existing capacity as presented in the paper. The committee also wants to explore the availability of data on sediments of debris deposition or replenishment from other institutions. The committee also needs to obtain GIS data from other sources too. The committee agreed on presenting an intermediate/preliminary report and a detailed factsheet before the next hearing of the matter i.e. 02/04/2024 and an additional time of 02 months may be sought form Hon'ble NGT to prepare the final report.



**The intermediate report on this matter is being submitted before Hon'ble National Green Tribunal (Principal Bench).**

**INTRODUCTION**

The majestic Himalaya, literally means the adobe of snow, widely known as the third pole due to the presence of the largest reserve of freshwater outside the polar regions and one of the globally recognized biodiversity hotspots, is a discrete geographic and ecological entity. The variations in topographical features result in diverse climate and habitat conditions within this region that have caused overwhelming richness, representativeness and uniqueness. Most of the perennial rivers of our nation are from the Himalayan Mountain and are the lifeline of the northern region. The Himalaya is considered as the youngest mountain and was formed by the sediment of ancient Tethys Sea. This sediment is carried by the Himalayan rivers and deposited in the northern plain in the form of fertile soil, making the plain one of the most fertile lands in the world. It has been estimated that the Ganga and Indus carry 19 and 10 lakh tonnes of silt per day, respectively (www.inindiaaa.com). On the other hand, presently, the sediment loads available in the valleys are being considered are generated by earthquake activities in the Himalaya and associated landslides.

The Himalaya provides a huge scope of tourism due to its scenic beauty and healthy environment. Beautiful landscapes in the Himalayan Mountain offers a great tourist spot. Millions of tourists from different parts of the country as well as from abroad through the Himalayan tourist centres to enjoy their natural beauty. The increasing popularity of winter sports and the craze to enjoy snowfall has increased the rush of tourists in winters also. Apart from its beautiful scenery and its significance as tourist place, Himalaya are proud of being studded with sanctified shrines. Every year thousands of pilgrims' trek through the difficult terrain of the Himalayas to pay their reverence to these sacred shrines. Badrinath, Kedarnath, Tungnath, Gangotri, Yamunotri, etc. are some of the important places of pilgrimage.

In view of the importance of the Himalaya and recorded impacts of climate change coupled with anthropogenic activities, the mountain ecosystem is considered vulnerable and different precautions to conserve the ecosystem are in progress. One among the conservation initiatives, based on the research review in Himalaya, is an article published in Volume 125, number 8, dated 25.10.2023 in 'Current Science' on 'Need to declare the Higher Himalaya an eco-sensitive zone'. Further, the article also proposed that the river stretches between the headwaters till the southern flank of the Main Central Thrust (MCT), covering a stretch of around 125 km should be declared as an eco-sensitive zone (with a figure showing the rectangle on the map of digital elevation model). The Hon'ble National Green Tribunal (NGT) considered the issues and suggesting that due to constant damage and deterioration of natural conditions of the area, it is necessary to examine the factual data on the publication on the issues of Higher Himalaya should be declared as an "Eco Sensitive Zone", as proposed.

*K Chandrasekhar*    

In the above context, the Hon'ble NGT would like to find the factual report by constituting a joint Committee comprising of, i. a senior representative of Ministry of Environment, Forest and Climate Change (MoEFCC); ii. an Expert nominated by Director, GB Pant National Institute of Himalayan Environment, and iii. a Professor nominated by the Director, IIT Roorkee (Expert in the field of Civil Engineering). Further, with due acceptance, the MoEFCC issued an order no. 11/14/2023-ESZ dated 26<sup>th</sup> February 2023 constituted a joint committee for examination and submission of factual report for the above issue.

### **FACTS OF DATA REFERRED IN THE ARTICLE**

The recent disasters in Uttarakhand, India (e.g. 2013 Kedarnath, 2021 Rishi Ganga and 2023 Joshimath) and Himachal Pradesh (e.g. 2000 and 2013 Satluj-Kinnaur floods and 2023 Beas floods) not directly relevant to the anthropogenic activities and the quoted reference on 'Nature geoscience' volume number 7, published on 14<sup>th</sup> September 2014 ([www.nature.com/naturegeoscience](http://www.nature.com/naturegeoscience)) relevant to recent arctic amplification and extreme mid-latitude weather, not directly showing the anthropogenic impact on Higher Himalayan valleys.

As per Searle and Treloar, (2019), the Himalayan mountains are structurally divided into, the Indus–(Yarlung Tsangpo) suture zone, the Tethyan Himalaya sedimentary units, Greater Himalaya Sequence (GHS) metamorphic rocks, the Lesser Himalaya fold-and-thrust belt and the Sub-Himalaya Siwalik molasse basin present along the entire 2000 km length of the Himalaya (Figure 1 & 2). Likewise, the major structures, the Indus–Yarlung Tsangpo suture with north vergent backthrusts, the South Tibetan Detachment system (STDs) low-angle normal fault, locally called the Zaskar Shear zone in the west, the Main Central Thrust (MCT) zone and the Main Boundary Thrust are all mapped along the entire length of the mountain belt between the western (Nanga Parbat) and eastern (Namche Barwa) syntaxes. Klippen of low-grade or unmetamorphosed sedimentary rocks lie above the GHS high-grade rocks in places (e.g. Chamba klippe in India; Lingshi klippe in Bhutan), and far-travelled klippen of GHS rocks occur in places south of the main MCT and GHS rocks (e.g. Darjeeling klippe). The MCT of Himalaya covers all the areas, not only limited to Uttarakhand and Himachal Pradesh (please see the figure 1 and 2 attached).

Geomorphologically, the area is rugged, with narrow and wide valleys and convex slopes lies majorly in three main zones: the lower fluvial zone, the middle paraglacial zone (below 2500 m asl), and the upper glaciated terrain (over 3500 m asl). In the Himalayan segment (Upper catchment reaches), the drainage system and the characteristics of landforms are closely interdependent and interrelated. Morainic deposits are found along the steep channels located in upper catchments, highlighted with geomorphic features such as interlocking spurs, steep rock benches, gorges and stream terraces. Large terraces formed over a long period of time can be seen in the lower course of the river.

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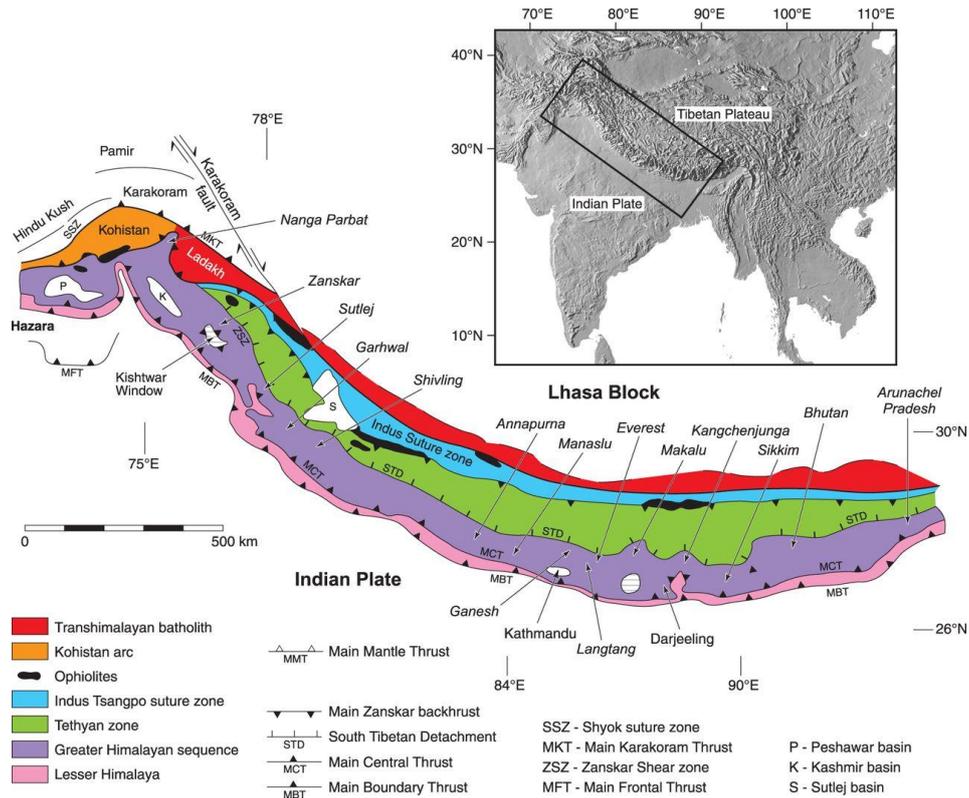


Figure 1. Geological map of Himalaya (Source: Searle and Treloar, 2019)

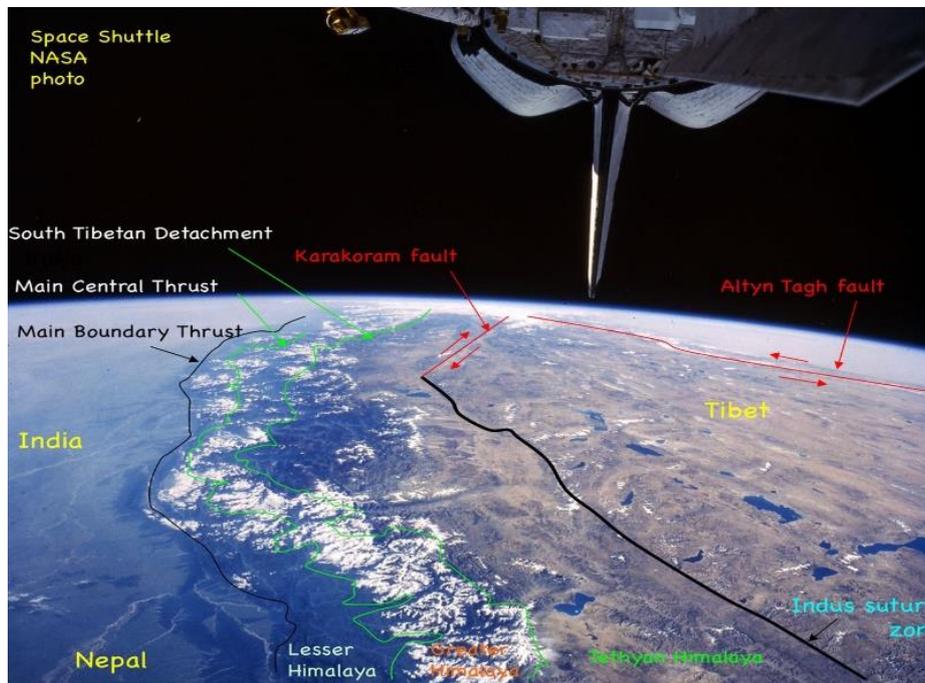


Figure 2. Photograph taken from the Space Shuttle looking west along the Himalaya with the outline of the major structural divisions and major faults of the Himalaya (Source: Searle and Treloar, 2019).

*Handwritten signatures in blue ink:*  
 K.K.      Anil      R.A.      R Chandrasekhar      Singh

## FACT SHEET

ARTICLE INFORMATION	FACT REPORT ANALYSIS (WITH REFERENCES)
<p>The recent disasters in Uttarakhand, India (e.g. 2013 Kedarnath, 2021 Rishi Ganga and 2023 Joshimath) and Himachal Pradesh (e.g. 2000 and 2013 Satluj–Kinnaur floods and 2023 Beas floods) have reignited the debate of anthropogenic impact on Higher Himalayan valleys and potentially increased impact of disasters in the region (Cohen, J. <i>et al.</i>, <i>Nature Geosci.</i>, 2014, 7(9), 627–637)</p>	<p>A large number of extreme rainfall events have been reported over the past decade, especially in the Northern Hemisphere mid-latitudes (Cohen et al., 2014). The rise in the average winter temperature also impacted the glacier and glacial landscapes in the mountainous region, including the Himalayas (Mehta et al., 2021). Subsequently, the frequency and intensity of landslides and floods over mid-latitude land areas (20–50° N) with especially rapid changes since the 1990s (Cohen et al., 2014). The long-term climatic trend of minimum temperatures shows a notably higher warming over the Himalayan basins reported (Rajbhandari et al., 2015; Sobin et al., 2020). However, various studies are available that hint towards the warming is because of an increase in anthropogenic greenhouse gas concentrations (IPCC 2007, 2013; You et al., 2017).</p>
<p>It is feared that under the impending climate change scenario, the sustainability of the geologically fragile Higher Himalayan ecosystem would be threatened, endangering the safety of infrastructure such as habitation sites, roads and hydropower projects.</p>	<p>Flash floods are one of the worst natural hazards in the Himalaya, which can result in disastrous effects on the lives, properties, and infrastructures and also trigger other disasters like the occurrence of landslides and outburst floods (Sagwal et al., unpublished). In the changing climatic scenario, geology and geomorphologic conditions of the terrain are the important parameters to be explored before establishing any infrastructure or habitat in the active Himalayan belt.</p>
<p>This is manifested by the over-steepened topography, the presence of convexity along the river longitudinal profile, and the development of stationary Knick points. These features suggest that uplift (convergence) is outpacing the incision (downcutting by the river), thus implying that</p>	<p>The Himalaya has a specific orography that allows the terrain to experience the full spectrum of rainfall at frontal and central Himalaya (Bookhagen and Burbank, 2010; Ray and Srivastava, 2010; Kumar and Srivastava, 2017) and because of its fragile landscape, steep orography and high relief terrain, it is extremely susceptible to</p>

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<p>the slopes of the Higher Himalayan valleys are unstable.</p>	<p>cloudburst-triggered hazards such as debris flows, flash floods, and landslides (Sharma et al., 2023). Flash floods in Himalaya are recurrent and devastating incidents. An increase in channel gradients via, for example, tectonic forces increase the unit stream power and subsequently enhance the channel incision rates (Devrani et al., 2015).</p>
<p>The Himalayan rivers contribute ~10% of the total global sediment budget, where ~44% of total sediments are stored in the glacially scoured Higher Himalayan valleys (Blöthe, J. H. and Korup, O., <i>Earth Planet. Sci. Lett.</i>, 2013, 382, 38–46). Therefore, it is considered that the Higher Himalayan valleys are sediment-surplus and transport-limited. These sediments are left behind by the receding glaciers, and the valleys where they are sequestered are called the paraglacial valleys (zones), having reasonably long sediment residence time (<math>10^3</math>–<math>10^4</math> years). A study pertaining to past floods in the Alaknanda valley suggested that since the last 6000 years, multiple floods have originated from the Higher Himalaya (around the MCT), transporting 86–45% sediment (Sundriyal, Y. P. et al., <i>Episode</i>, 2015, 38, 179–188). Similarly, studies in the Satluj basin indicated that the Higher Himalayan paraglacial valleys have been the source of sediments for the last 14,000 years (Sharma, S., Shukla, A. D., Bartarya, S. K., Marh, B. S. and Juyal, N., <i>Geomorphology</i>, 2017, 290, 317–334).</p>	<p>Suspended sediment budgets, on a basin scale, are mainly used as an indicator of sediment mobilization and sediment evacuation mechanisms. A significant change in sediment rates in the basin during any season may be understood as channel instability in the glaciated region, hydroclimatic control, meltwater discharge, and sediment stored within the subglacial waters (Kumar et al., 2018). Studies on the Gangotri glacier basin by Kumar et al. (2002) estimated the total suspended sediment for a period of two ablation seasons (1999 and 2000). The total suspended sediment was <math>165.62</math> and <math>104.99 \times 10^4</math> t, respectively. Haritashya et al. (2006) also estimated the average suspended sediment yield for the whole melt season for the period 2000–2003 to be about <math>4834 \text{ t km}^2</math> with the corresponding erosion rate of <math>1.8 \text{ mm}</math>. The sediment yield for the basin was <math>\sim 2863 \text{ tonnes km}^{-2} \text{ yr}^{-1}</math>. For the entire ablation period, the erosion from the Gangotri Glacier basin is estimated to be about <math>1.0 \text{ mm}</math>. Gangotri Glacier drainage basin, Garhwal Himalaya, was studied for the years 2008–2011 to assess the suspended sediment concentration (SSC), load, yield, and erosion rate (~50% glaciated area). Mean monthly SSCs from May to September 2008–2011 were 1,011, 1,384, 1,916, 1,675, and 567 ppm, respectively, indicating the highest in July and August with a mean value of 1,320 ppm (Arora et al., 2014).</p> <p>In the Himalaya, the history of past large floods suggests the frequency of such floods</p>

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	<p>has increased (Wasson et al., 2013; Sharma et al., 2017; Srivastava et al., 2017). A study using past flood deposits from the Garhwal Himalayan region established that ~40 large floods have occurred during the last millennium, mostly during periods of warm climatic conditions, often as a result of Landslide Lake and Glacial Lake Outburst Floods (LLOFs and GLOFs, respectively) (Wasson et al., 2013). A review of past floods in the Himalayas also shows that rivers witnessed a higher frequency of large floods during warmer climatic spells in the past 11000 years (Wasson et al., 2013; Srivastava et al., 2017).</p>
<p>In the upper Ganga catchment, during the 20 July 1970 Alaknanda flood, <math>\sim 15.9 \times 10^6</math> tonnes of sediment was generated within a 30 km radius of the MCT (Sundriyal, Y. P. <i>et al.</i>, <i>Episode</i>, 2015, 38, 179–188). Similarly, in 2013, most of the sediments were mobilized from the Higher Himalaya responsible for the destruction of under-construction and operational barrages along the Mandakini, Alaknanda and east Dhaul Ganga rivers (Sundriyal, Y. P. <i>et al.</i>, <i>Episode</i>, 2015, 38, 179–188). The eastern Dhaul Ganga transported <math>\sim 6.2</math> million cubic metres of sediment during June 2013 and filled an operational dam (above Dharchula) with <math>\sim 2.8</math> million cubic metres of debris in just a one-day flood event (Sundriyal, Y. P. <i>et al.</i>, <i>Episode</i>, 2015, 38, 179–188). These sediments sometimes damage the hydropower project gates constructed in the Higher Himalaya. For example, the radial gates of the Vishnuprayag Hydropower Project in the Alaknanda Valley were damaged during the June 2013 floods and, more recently, during the July 2023 Beas floods, the Malana dam gates were obstructed by sediments in the Parvati valley.</p>	<p>The sediment generated during the Kedarnath disaster in 2013 has been studied to understand nature and the causes of destruction in the Mandakini and Alaknanda river valleys (Sundriyal et al., 2015). The sediments were sourced mainly from glaciogenic material, alluvial fans and landslides located in the Trans and Higher Himalaya. During this event, <math>&gt;0.35 \text{ M m}^3</math> of sediment was transported from the upper glacial to lower paraglacial regions. Nevertheless, a gigantic volume of sediment is still available at Sonprayag and Sitapur villages for scavenging downstream regions. At these locations, the riverbed rose <math>\sim 29 \text{ m}</math> due to sediment aggradation. Further, in the Gohna Lake outburst flood on July 20th, 1970, the MCT zone transported <math>\sim 15.9 \times 10^6</math> tons of sediment (Kumar and Shone, 1970). Sundriyal et al. (2015) also claimed that the terrain north of the Main Central Thrust (MCT), i.e., Higher Himalaya, should be avoided for human intervention, i.e., construction of hydropower projects, etc., to reduce flood hazards.</p>
<p>Unusual weather events in the Himalaya are showing an increasing trend. This is manifested by the rise in the frequencies and</p>	<p>The long-term climatic trend of minimum temperatures shows a notably higher warming over the Himalayan basins</p>

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<p>magnitude of springtime forest fire events, avalanches, flash floods and land-slides. Is this an unpredictable response to climate warming in the Himalayan region? Global warming is more rapid at higher elevations, attributed to elevation-dependent warming. It is projected that by the end of the 21st century, the temperature in the Higher Himalayan region will be between 2.6°C and 4.6°C (Sabin, T. P., Krishnan, R., Vellore, R., Priya, P., Borgaonkar, H. P., Singh, B. B. and Sagar, A., In <i>Assessment of Climate Change over the Indian Region: A Report of the Ministry of Earth Sciences (MoES), Government of India</i> (eds Krishnan, R. et al.), Springer, Singapore, 2020, pp. 207–222)</p>	<p>reported (Rajbhandari et al., 2015; Sobin et al., 2020). However, various studies are available that hint towards the warming is because of an increase in anthropogenic greenhouse gas concentrations (IPCC 2007, 2013; You et al. 2017). The annual mean temperature time series averaged (from 1951 to 2018) indicating the Himalaya region is warmer over the Indian landmass (Sobin et al., 2020).</p>
<p>Consequently, it can be speculated that the unstable paraglacial sediments sequestered in the Higher Himalayan valleys, if not allowed to flow freely (obstructed by built-up structures), will adversely impact the infrastructures (Sati, S. P., Sharma, S., Sundriyal, Y. P., Rawat, D. and Riyal, M., <i>Geomat. Nat. Haz. Risk</i>, 2020, 11(1), 887–905)</p>	<p>Sundriyal et al (2015) calls for a critical re-evaluation of policies made for development works and draws rein a large number of the hydropower potential of the Himalayan rivers in general. There is an urgent need for a detailed investigation of geology, geomorphology, ecology and biodiversity prior to implementing the hydropower projects in the Higher Himalaya where the occurrence of landslides, slope instability and floods are very frequent (Sati et al., 2020).</p>
<p>In addition, the increasing anthropogenic interventions are adversely impacting the stability of the precariously stabilized valley slopes, as seen in the recent example of Joshimath town in Uttarakhand (Sati, S. P., Asim, M., Sundriyal, Y. P., Rana, N., Bahuguna, V. and Sharma, S., <i>Curr. Sci.</i>, 2023, 124(12), 1384–1392)</p>	<p>The Joshimath town is situated on a previous landslide debris that has low bearing capacity (Misra, 1976. Committees report on sinking of Joshimath. Government of Uttar Pradesh) and further suggested that ‘For further road construction, it would be advisable not to remove boulders by digging or blasting the hill side...’. The report also stated that undercutting by river currents of Alaknanda and Dhauliganga are also playing their part in bringing landslides’. Further, water percolation has decreased the cohesive strength of the rocks over the time (<a href="http://www.thethirdpole.net/en/energy/joshimath-disaster-of-ignoring-risks-in-the-himalayas">www.thethirdpole.net/en/energy/joshimath-disaster-of-ignoring-risks-in-the-himalayas</a>).</p>

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A recent study by Li *et al.* (Li, D. *et al.*, *Nature Geosci.*, 2022, 15(7), 520–530; <https://doi.org/10.1038/s41561-022-00953-y>) warned that global warming-induced melting and thawing of the cryosphere is likely to impact High Mountain Asia, which would adversely affect the down-stream food and energy systems, particularly the hydropower projects in the Higher Himalaya that are vulnerable to a complex set of interacting processes.

There is substantial support in literature for the disproportionate increase in the temperature in the higher Himalaya as mentioned in the cited article by Li *et al.*, 2022. In addition to the increased melting and thawing in the focussed area, the region also has higher erosion rate (partly due to the young and steep nature of the mountains and partly due to the increased thawing and flow). A logical consequence of increased thawing and erosion would be additional stress and challenges to the hydrological structures in the proposed ESZ and downstream. The extent of the impact of the increased temperatures on the performance of hydrological structures in the region and subsequently on the irrigation-dependent food production needs to be investigated.

### PROPOSED ESZ AREA

As per the article published in the Current Science, the proposed area of Eco-Sensitive Zone, the river stretches between the head-waters till the southern flank of the Main Central Thrust (MCT) covering a stretch of around 125 km. The specified area has been studied in different aspects and prepared the following GIS-based maps:

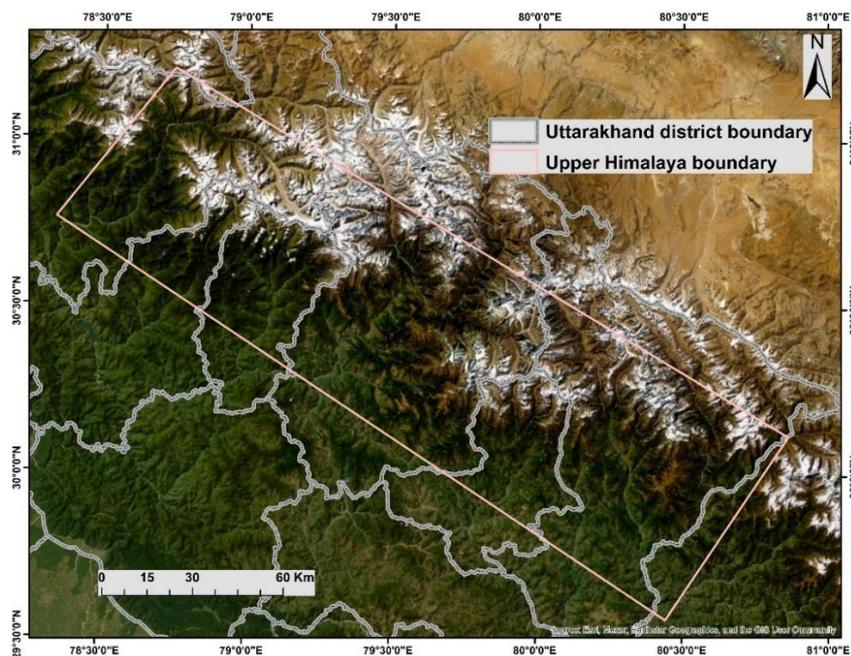


Figure 3. The Himalayan range with the proposed ESZ area.

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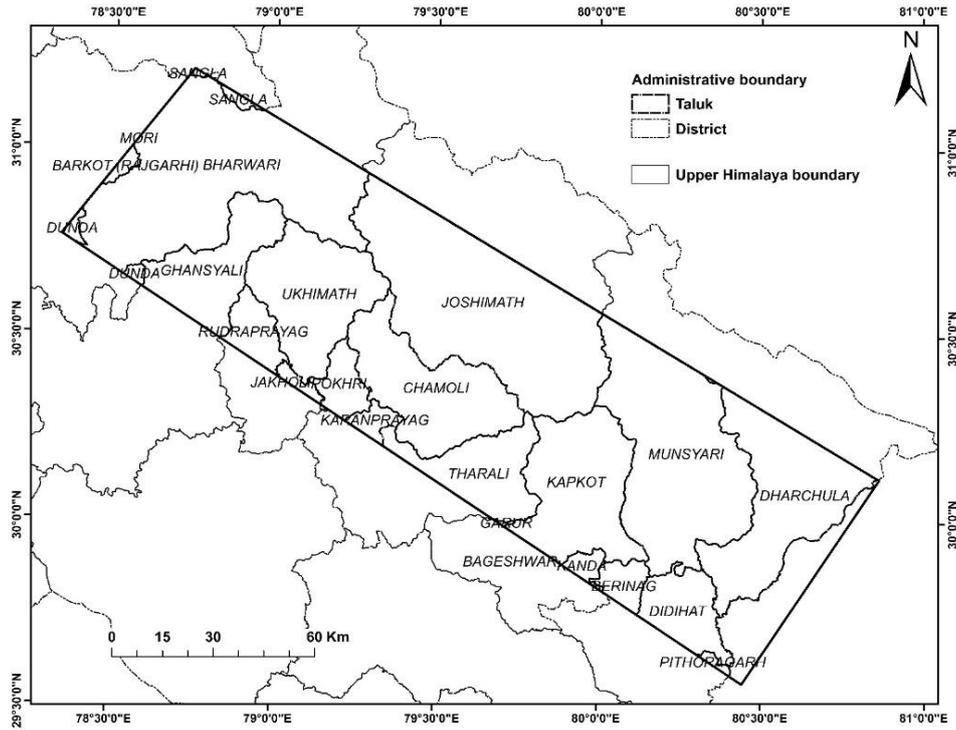


Figure 4. District and Tehsil boundaries of proposed ESZ area.

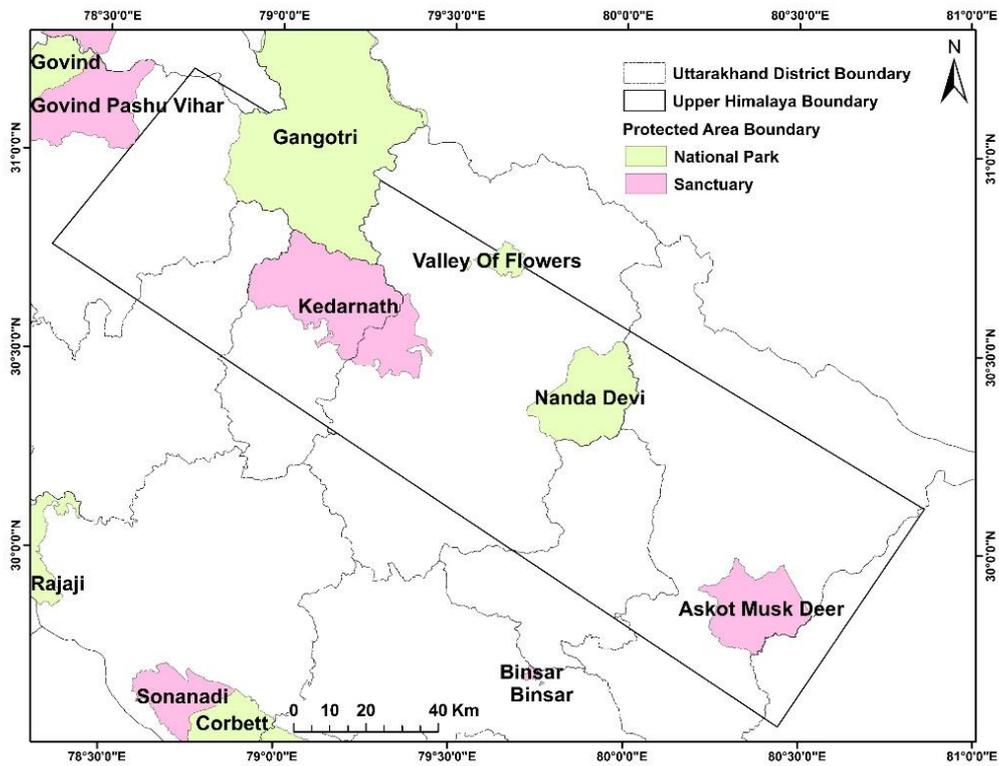


Figure 5. Protected Area in proposed ESZ area

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S. Singh

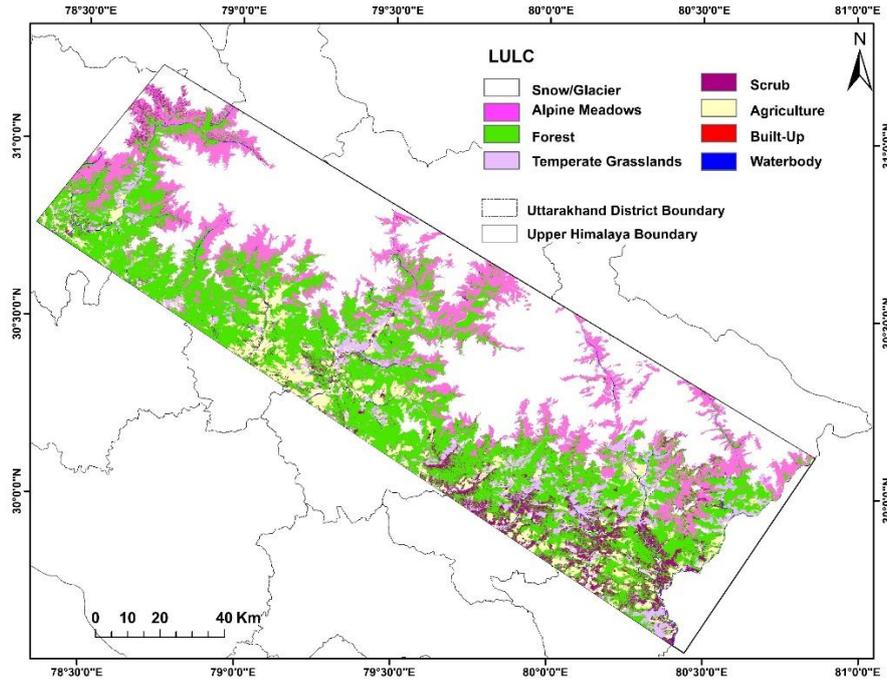


Figure 6. Vegetation type map of the proposed ESZ area.

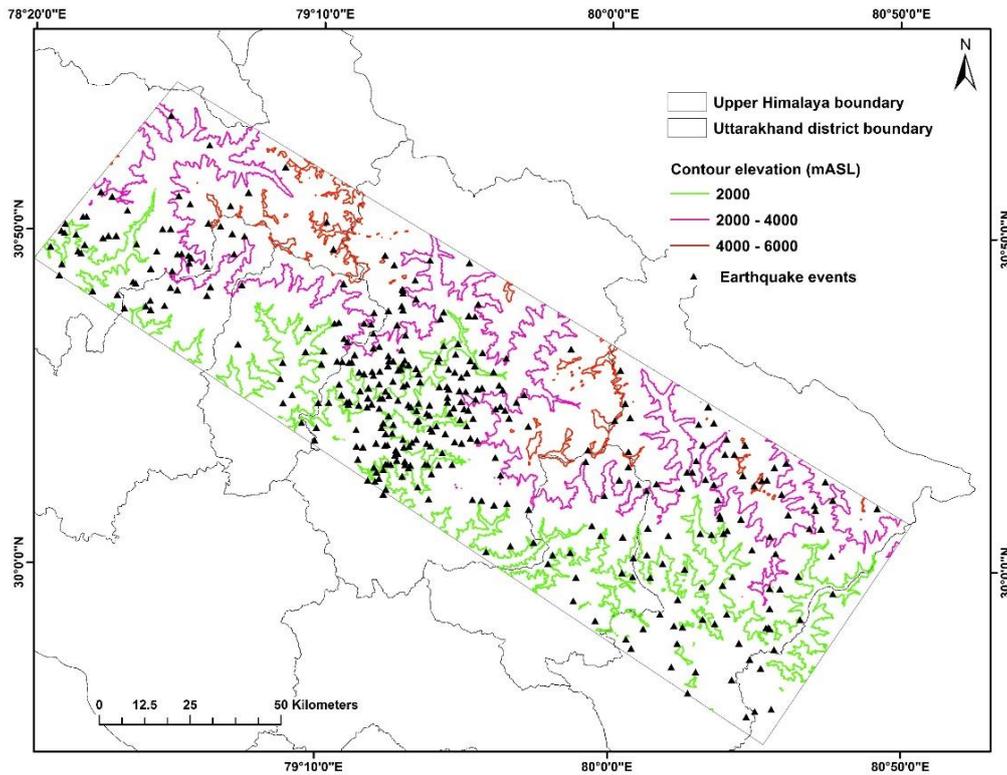


Figure 7. Elevation zone of the proposed ESZ area.

*K Chandrasekhar*  
*[Signature]* *[Signature]* *[Signature]* *[Signature]*

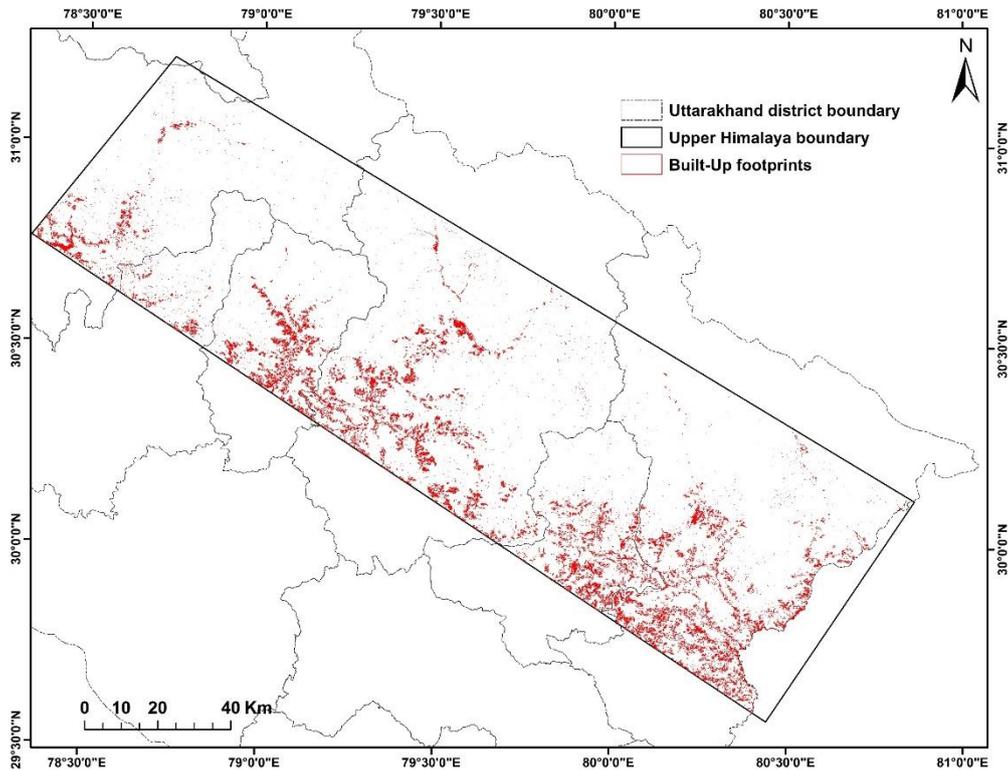


Figure 8. Upper Himalaya Building Footprint map.

The delineated area of the proposed ESZ is 16205.30km<sup>2</sup> (Figure 3) and covered in the six districts of Uttarakhand State namely, Uttarkashi, Tehri Garhwal, Rudraprayag, Chamoli, Bageshwar and Pithoragarh (Figure 4). Further, the proposed area has well established Protected Area (PA), i.e., National Park (NP) and Wildlife Sanctuary (WLS). The prominent PA are, the Gangotri NP, Valley of Flowers NP, Nanda Devi NP, Kedarnath WLS and Ashot Musk Deer WLS. The boundary of the Govind NP has been touched with the proposed area. In the total area 21% area is (3391.347 km<sup>2</sup>) covered by the PA network (Figure 5). While analysing the vegetation zone areas, the snow cover areas are higher in comparison with other dominant communities (Figure 6). The 3000-5000m elevations are dominated in the elevation map (Figure 7). To assess the anthropogenic activities, building footprint of upper Himalaya is given in figure 8.

### Sediment information on the proposed ESZ area

Suspended sediment budgets, on a basin scale, are mainly used as an indicator of sediment mobilization and sediment evacuation mechanisms. A significant change in sediment rates in the basin during any season may be understood as channel instability, hydroclimatic control, meltwater discharge, and sediment stored within the subglacial waters (Kumar et al., 2018). Studies on the Gangotri glacier basin by Kumar et al. (2002) estimated the total suspended sediment for a period of two ablation seasons (1999 and 2000). The total suspended

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sediment was  $165.62$  and  $104.99 \times 10^4$  t, respectively. Haritashya et al. (2006) also estimated the average suspended sediment yield for the whole melt season for the period 2000–2003 to be about  $4834 \text{ t km}^2$  with the corresponding erosion rate of  $1.8 \text{ mm}$ . The sediment yield for the basin was  $\sim 2863 \text{ tonnes km}^{-2} \text{ yr}^{-1}$ . For the entire ablation period, the erosion from the Gangotri Glacier basin is estimated to be about  $1.0 \text{ mm}$ . Gangotri Glacier drainage basin, Garhwal Himalaya, was studied for the years 2008–2011 to assess the suspended sediment concentration (SSC), load, yield, and erosion rate ( $\sim 50\%$  glaciated area). Mean monthly SSCs from May to September 2008–2011 were 1,011, 1,384, 1,916, 1,675, and 567 ppm, respectively, indicating the highest in July and August with a mean value of 1,320 ppm (Arora et al., 2014). A summary of suspended sediment yield is provided by Kumar et al. (2018), see table 1.

Table 1. Summary of Suspended Load Yield (SSY) over the Higher Himalayan basins (Kumar et al., 2018)

Glacier	Basin/Region	Catchment area (km <sup>2</sup> )	Specific SSY (t/yr. km <sup>2</sup> )	Observation period	References
Chorabari	Mandakini/ Central Himalaya	15.4	4,064.3	(June-Sept., 2009-2012)	Kumar et al. (2016)
Dokriani	Bhagirathi/ Central Himalaya	16.1	2,800.0	(June-Sept., 1995-1998)	Singh et al. (2003)
Dunagiri	Dhauliganga / Central Himalaya	17.9	296.3	(July-Sept., 1984-1989)	Srivastava et al. (2014)
Gangotri	Bhagirathi/ Central Himalaya	556.0	4,834.0	(May-Oct., 2000-2003)	Haritashya et al. (2006)
			2,863.0	(May-Oct., 2008-2011)	Arora et al. (2014)
			7,663.0	(May-Sept., 2008)	Singh et al. (2014)

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The sediment generated during the Kedarnath disaster in 2013 has been studied to understand nature and the causes of destruction in the Mandakini and Alaknanda river valleys (Sundriyal et al., 2015). The sediments were sourced mainly from glaciogenic material, alluvial fans and landslides located in the Trans and Higher Himalaya. During this event,  $>0.35 \text{ M m}^3$  of sediment was transported from the upper glacial to lower paraglacial regions. Nevertheless, a gigantic volume of sediment is still available at Sonprayag and Sitapur villages for scavenging downstream regions. At these locations, the riverbed rose  $\sim 29 \text{ m}$  due to sediment aggradation. Further, in the Gohna Lake outburst flood on July 20th, 1970, the MCT zone transported  $\sim 15.9 \times 10^6$  tons of sediment (Kumar and Shone, 1970).

Sundriyal et al. (2015) also claimed that the terrain north of the Main Central Thrust (MCT), i.e., Higher Himalaya, should be avoided for human intervention, i.e., construction of hydropower projects, etc., to reduce flood hazards. The study finally calls for a critical re-evaluation of policies made for development works and draws rein a large number of the hydropower potential of the Himalayan rivers in general. There is an urgent need for a detailed investigation of geology, geomorphology, ecology and biodiversity prior to implementing the hydropower projects in the Higher Himalaya where the occurrence of landslides, slope instability and floods are very frequent (Sati et al., 2020). Mehta et al. (2017) estimated the sediment volume associated with the Kedarnath disaster in 2013. It is suggested that  $3.9 \times 10^6 \text{ m}^3$  volume of debris was deposited in Kedarnath town, and nearly  $2.6 \times 10^8 \text{ m}^3$  volume of debris was removed from Rambara and surrounding areas. Villages like Lambaghar, Bhyundar (Alaknanda valley), and Rambara (Mandakini valley) were completely eroded. In Alaknanda valley, Govindghat and Pulna villages were also severely damaged where  $\sim 0.3 \times 10^6$  and  $0.72 \times 10^6 \text{ m}^3$  of debris was deposited, respectively. Similarly, in the Mandakini Valley, Kedarnath and Sonprayag towns,  $\sim 3.9 \times 10^6$  and  $\sim 1.4 \times 10^6 \text{ m}^3$  of debris were deposited, respectively.



Figure 9. The photograph shows the damage during the Rishiganga flood in 2021. (a) and (b) show the damage to the bridge at Raini village, (c) the development of slacking conditions at the confluence of the Rishiganga and Dhauliganga rivers, and (d) the damage to Tapovan hydroelectric power project barrage (Sain et al., 2021).

Certainly, in the Higher Himalaya, the glacier processes are dominant, and hence, these processes have both long-term and short-term impacts on society. The fluctuations in the glacier volume, temperature, and precipitation will lead to a scarcity of availability of water in the near future. Recently, hazards such as snow avalanches, glacial lake outburst floods (GLOFs), flash floods, debris flows, etc., made the terrain vulnerable. The frequency of such events may increase, as the glaciers recede in response to climatic variability (Sain et al., 2021; Shugar et al., 2021). The figure 9 suggests that during the Rishiganga flood disaster in 2021, a huge amount of sediment was mobilized from the higher/trans-Himalaya that destructed, the lower valleys. This suggested an enormous volume of sediment is already available in the Higher Himalayan valleys to create the next disaster in the downstream regions.

Another study using satellite remote sensing, numerical modelling, and field observations reconstructed the channel response affected by the 7 February 2021 ice-rock avalanche–debris flow in Chamoli district, Uttarakhand, India (Westoby et al., 2023). The sediment-laden channel deposited  $10.4 \pm 1.6 \text{ Mm}^3$  of sediment within 30 km (upstream region)

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and, in places, reset the channel floor to maintain the steady state condition. After one-year post-event,  $7.0 \pm 1.5 \text{ Mm}^3$  (67.2%) of the sediment volume was removed, with a median erosion rate of  $2.3 \pm 1.1 \text{ m a}^{-1}$ . The study suggested that most of the sediment was removed by pre-monsoon and monsoon river flows. This spatiotemporal sediment deposition and erosion provide a vague picture to the geoscientists however, erosion enhanced in the valleys where the geomorphology of the basin has changed after the flood events and need to re-evaluated for future risk (Westoby et al., 2023).

### Hydrological information on the proposed ESZ area

The upper Himalayan region that is the focus of this report is extremely important from perspective of fresh water resources available to India, as multiple important tributaries of river Ganga originate here and meet the water needs of 40% of the population of the country. The tributaries and sub-tributaries in the region can be broadly classified into three major basins: Bhagirathi basin, Alaknanda basin, and Kali basin. The Alaknanda basin comprises Upper Alaknanda, Mandakini, Dhauliganga, and Pindar catchment, while the Kali basin comprises catchments of Goriganga and Kali/Sarda (Bandyopadhyay et. al., 2019). Many of these tributaries and their sub-tributaries rely on glacial melt, with glaciers in turn being fed by summer monsoon and winter snow regimes (Dobhal et. al., 2008). Over multiple decades several small and large hydraulic structures have modified the flow regime, particularly in the Bhagirathi basin (Swarnkar et. al., 2021). It is important to note that the glaciers and the rivers in the region are very sensitive to both the changes in climate and the developmental efforts that change the course of rivers, partly due to steep and relatively less stable valley slopes.

### Bhagirathi basin

In the Bhagirathi basin, the Bhagirathi river originates at Gaumukh and ends at Devprayag passing through Uttarkashi, Tehri and Pauri Garhwal district with total basin area of  $7619 \text{ km}^2$ . The basin has high mountain chains and glaciated area in north. The Bhagirathi River basin contains  $\sim 238$  glaciers covering  $\sim 755 \text{ km}^2$  (Ghosh et. al., 2019). Many glaciers in the Bhagirathi basin has comparatively higher debris-covered glacial areas with overall debris-covered area about  $\sim 26.4\%$  of the whole ice cover. Glaciers range in size from  $0.21$  to  $132.7 \text{ km}^2$ , with a mean of  $13.7 \text{ km}^2$  in the upper Bhagirathi basin (Bhambri et. al., 2011). Some of the important glaciers in the Bhagirathi river basin are Gangotri, Chaturangi, Kirti Bamak, Raktavaran, and Kedar Bamak (Bhambri et. al., 2011).

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Over the years, the glaciers in the region have receded or split with an acceleration attributable to the changing climate. For example, Kumar et. al., 2021 report that during 1968 to 2019 the Swetvarn glacier snout lost ~623 m total length with  $12.21 \text{ ma}^{-1}$  retreat rate, while the Thelu glacier snout lost ~590 m total length ( $11.56 \text{ ma}^{-1}$ ) (Kumar et. al., 2021). In the upper Bhagirathi basin, the glacierized area changed from  $275.1 \pm 7.5 \text{ km}^2$  (1968) to  $266.1 \pm 8.3 \text{ km}^2$  (2006), a decrease of  $8.9 \pm 7.9 \text{ km}^2$  or  $3.3 \pm 2.8\%$ . The loss in glacier area ranged from 2% to ~28% in this basin. The debris-covered glacier area increased by  $11.8\% \pm 3.0\%$  ( $0.3 \pm 0.08 \text{ a}^{-1}$ ) in the upper Bhagirathi basin from 1968 to 2006 (Bhambri et. al., 2011). The ongoing shift towards increased liquid precipitation compared to snow has made this basin increasingly susceptible to flash floods and landslides (Arora et. al., 2014). The ever-increasing intensity of the rainfall events also pose a risk to the stability of the moraine-dammed lakes in the basin (Singh et. al., 2018).

The rivers and tributaries in the Bhagirathi basin are primarily responsible for controlling the available water for filling the Tehri reservoir. The rainfall occurring in summer and winter precipitation (snow and rain) over the basin determine the amount of runoff available for filling the Tehri reservoir (Dimri et. al., 2023). Since the Bhagirathi basin relies on precipitation for the amount of flow in the rivers, the reduction in the magnitude of the rainfall over past few decades, the flow in the rivers in this basin is largely controlled by the dams in this region, such as the Maneri dam and Tehri dam (Swarnkar et. al., 2021). The substantial amount of sediments trapped in the Tehri and Maneri reservoirs indicates that the hydraulic structures have significantly disrupted the upstream–downstream geomorphologic linkages and the channel morphology downstream. Several of the hydraulic structures in the region were designed based on analysis of past-extreme floods, but the flood events are getting more extreme and need fresh suitability analysis for sustainable river basin management.

**Alaknanda-Mandakini basin:** The Mandakini originates from the Chorabari Glacier (~ 5020 m) and joins Alaknanda at Rudraprayag (~ 431 m). On the way, it passes through Kedarnath, Chunni and Sumari, covering major hydropower projects Kund and Tilwara. Alaknanda originates from Satopanth Glacier (~ 4350 m amsl) and passes through Badrinath, Karnaprayag, Rudraprayag and finally Devprayag (~ 475 m amsl) where it merges with the Bhagirathi. The combined area of the Mandakini River basin and Alaknanda River basin is  $12715 \text{ km}^2$  (Ghosh et. al., 2019).

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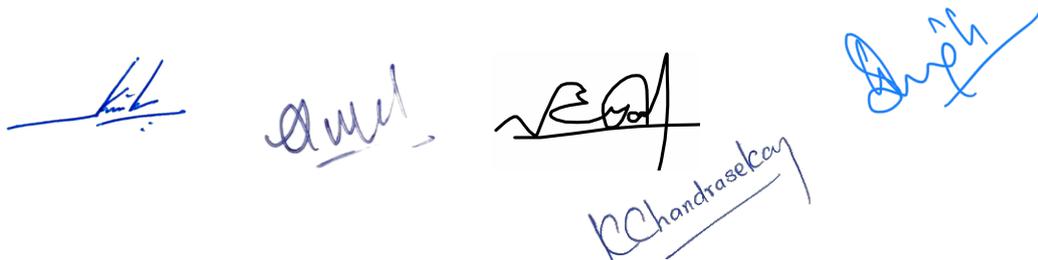
The Alaknanda and Mandakini basins have ~407 glaciers and 24 glaciers, respectively, covering a total of ~1229 km<sup>2</sup>, which equals 42% of all glaciers in the Garhwal. Of the 83 glaciers identified in the Saraswati/Alaknanda basin in 2006, 51 had debris-covered tongues (~24.6% of the total glacierized area). Some of the important glaciers in this river basin are Bhagirath Kharak, Satopanth, Chorabari, Andardip, Arwa, Baibala, Khulia Garvya, Pachim Kamet, and Panpatia Bank.

Similar to the Bhagirathi basin, the Alaknanda/Saraswati basin has also witnessed reduction in total area of glaciers, receding and splitting over the past six decades. In the Alaknanda/Saraswati basin, the area of the glaciers changed from 324.7 ± 8.4 km<sup>2</sup> (1968) to 306.3 ± 9.5 km<sup>2</sup> (2006), a decrease of 18.42 ± 9.0 km<sup>2</sup> or 5.7 ± 2.7%. The number of glaciers has also increased from 69 (1968) to 75 (2006) due to the disintegration of ice bodies. The loss in glacier area of individual glaciers ranged from 0.9% to 42.5%. On average, small glaciers (<1 km<sup>2</sup>) have lost ~19% of their area between 1968 and 2006 in the Saraswati/Alaknanda basin. South-facing glaciers have lost ~19.4% of their area, about four times more than for north-facing glaciers (~4.7%). The debris-covered glacier area has also increased by 17.8 ± 3.1% (0.46 ± 0.08% a<sup>-1</sup>) in the Alaknanda basin. The Alaknanda basin had free-flowing river until 2015 (Swarnkar et. al., 2021) and has witnessed some extreme flash flood events in recent years.

**Kali:** An important river in the Kali basin is Gauri Ganga, which starts from Milam glacier and borders Nanda Devi Sanctuary. Hydrological data for river Kali is relatively limited and will require additional time to compile the data.

### Task remaining

- Field survey of the proposed ESZ area (sample points) for field authentication and validation of datasets.
- Incorporation of existing ESZ of Protected Areas in the proposed zone and interpretation.
- Incorporation of boundary of Nanda Devi Biosphere Reserve (NDBR) area in the proposed ESZ for understanding the BR area network and interpretation.
- Refining the factsheet with more relevant literature and field-based data (if feasible).
- Preparation of suitable recommendations for sustaining the Himalaya with livelihood options.
- Expert consultation (on-line) and drafting the final report.



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