Uttarakhand Disaster 2013

nidm
Towards a disaster free India.....

National Institute of Disaster Management
(Ministry of Home Affairs, Govt. of India)

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New Delhi

ISBN: 978-93-82571-14-8
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Published by:
National Institute of Disaster Management (Ministry of Home Affairs, Government of India)
5-B, IIPA Campus, I.P. Estate, New Delhi – 110002, India
Tel. +91-1123702432, 23705583, 23766146
Website: www.nidm.gov.in

Overall Coordination:
Dr. Satendra, (then) Executive Director NIDM
Dr. Anil K. Gupta, Head, Division of Policy Planning, NIDM

Contributors /Editors:

- **Dr. Satendra, (then) Executive Director, NIDM**
- **Dr. Anil K. Gupta, Head, Policy Planning Division & Training Division, NIDM**
- Maj. Gen. (Dr.) **V. K. Naik, Senior Consultant, Policy Planning Division, NIDM**
- **Tapash Kumar Saha Roy, Consultant, Hydro-met Disaster Management Division, NIDM**
- **Ashok K. Sharma, Consultant, Response Division, NIDM**
- **Manas Dwivedi, Junior Consultant, Policy Planning Division, NIDM**

Review:
Dr. S. K. Mattoo, Former Chief Resident Commissioner, Government of Uttarakhand

Citation:
Satendra, A. K. Gupta, V. K. Naik, T. K. Saha Roy, A. K. Sharma, and M. Dwivedi (2014). Uttarakhand Disaster 2015. National Institute of Disaster Management, New Delhi, 184 Pages.

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Design and Printing:
M/S. Chandra Prabhu Printing Works Pvt. Ltd., C-40, Sector - 8, Noida - 201301

किरेन रीजीजू
KIREN RIJIJU

सत्यमेव जयते

No. MOS/Home/306054/108/2014
गृह राज्य मंत्री
भारत सरकार
MINISTER OF STATE FOR
HOME AFFAIRS
GOVERNMENT OF INDIA

MESSAGE

On 16 June 2013, the State of Uttarakhand suffered its worst disaster in the living memory resulting in huge loss to lives and wide spread destruction of infrastructure across the State.

The disaster has once again brought to fore the deficiencies in our collective preparedness against disasters. It is a stark reminder that while the developmental issues are inarguably significant, the aspects of sustainable development are equally important. Our unique geo-climatic conditions are unalterable, and we shall continue to face multiple hazards in future. India has undertaken significant initiatives towards disaster risk reduction and efficient disaster management in the recent past and we need to vigorously pursue the paradigm shift in disaster management from a "relief centric approach" to the ongoing "holistic approach" covering all facets of disaster management. The recurrence of disasters being inevitable, there are literally no options but to enhance our preparedness and reduce vulnerability to disasters. Mainstreaming of DRR into all the developmental activities across the nation is very important.

I am happy to note that the NIDM has undertaken the task of documenting the Uttarakhand disaster 2013 in a most professional manner and have prepared an exhaustive report. I am particularly pleased to note that the experts from the NIDM, including the Executive Director, had undertaken field visits to affected areas in June and July 2013, besides interacting with various stakeholders and role players, including communities, before compiling this report. The document covers the vulnerability of the State and causes of the disaster; the immediate response by the Central and the State Government; the impact and damage assessment; and recommends certain technical solutions for Reconstruction. The lessons learnt have been elaborated upon very systematically.

I am sure that the report will be invaluable to all the disaster management practitioners and it will meaningfully contribute towards fine tuning the disaster preparedness and mitigation initiatives in the country.

(Kiren Rijiju)

Dr. Pramod K. Mishra
Addl. Principal Secretary

सत्यमेव जयते

प्रधान मंत्री कार्यालय
नई दिल्ली - 110101
PRIME MINISTER'S OFFICE
New Delhi-110101

FOREWORD

The Uttrakhand disaster of June 2013 caused enormous damage, destruction and loss of life. The event has thrown up several questions relating to preparedness, mitigation and disaster risk reduction in the context of pattern of economic development.

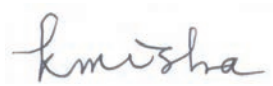
Another question is: why are the lessons of earlier disasters forgotten over time? There have been several disasters such as flood, cyclone, earthquake and tsunami in recent decades. Every disaster brings surprises and also important lessons. Experiences show that in case of most disasters the system appears unprepared and starts from the beginning. The same problems arise and the same mistakes are committed when a major disaster occurs, though there are a few exceptions.

One of the reasons for this phenomenon is that experiences and lessons of disasters are not well documented in India. There may be comprehensive media accounts, official reports and even research papers. But systematic documentation which can guide and facilitate disaster response and recovery is rare. A decade ago I had made an attempt to document the experiences of response, relief, recovery and reconstruction activities in the context of the Kutch Earthquake of 2001. It was published by the National Institute of Disaster Management (NIDM) in the form of a book. It was possibly NIDM's first publication.

I am delighted to know that the NIDM faculty has documented various aspects of the Uttrakhand disaster of 2013 in the form of a book. NIDM initiated the process of documentation immediately after the disaster event. Faculty members and researchers undertook field visits and conducted surveys. NIDM organized two national workshops with a view to sharing experiences and crystallizing the lessons learnt. It also held a series of meetings and discussions with experts and, more importantly, interacted with officials of the Government of Uttarakhand. Thus there was an elaborate process of consultation with various stakeholders. The book is the culmination of such an endeavour.

The book begins with a description of the vulnerabilities of the State to disasters and tries to analyse possible causes of the recent tragedy. Then it provides a chronological account of the event as it unfolded. It gives a detailed description of the large-scale rescue and relief operations undertaken in the aftermath of the disaster, highlighting significant aspects of the initiatives taken by the Government of India, the State government and other agencies. Then there is an assessment of the damage caused by the disaster. Based on the analyses and the relevant facts, an attempt has been made to identify the lessons learnt keeping in view various phases of the disaster management cycle: pre-disaster phase, preparedness, response and relief. The book suggests some approaches to reconstruction in Uttarakhand in order to provide technical guidance to those involved in the process. It also outlines certain measures for protection of the Kedarnath Shrine.

I compliment the NIDM team for the documentation, which is an important contribution to the literature on disaster management. I am sure, the book will be a useful reference for policy-makers, disaster management professionals, researchers and other stakeholders.



(Pramod K. Mishra)

स्नेह लता कुमार
सचिव (सीमा प्रबंधन)

SNEH LATA KUMAR
SECRETARY (BORDER MANAGEMENT)
Tel.: 23092440 Fax : 23092717
e-mail : Secybm@nic.in

सत्यमेव जयते

गृह मंत्रालय
भारत सरकार
नार्थ ब्लाक, नई दिल्ली - 110001

MINISTRY OF HOME AFFAIRS
GOVERNMENT OF INDIA
NORTH BLOCK, NEW DELHI-110001

FOREWORD

With its typical geo-climatic attributes and socio-economic conditions, Uttarakhand is one of the most disaster-prone States of the country. The State has been suffering from natural disasters frequently with an obvious impact on its economy and lives of its citizens.

The wide-spread heavy rains and flash floods, resulted in one of the most devastating disasters in the recent past in the region. The districts of Bageshwar, Chamoli, Pithoragarh, Uttarkashi and Rudraprayag including the Kedanrnath Shrine and the adjoining areas in the Mandakini valley were the worst affected. The impact of the disaster was pronounced as it coincided with the peak tourist season. The damage to infrastructure and loss of livelihoods have thrown up new challenges for recovery, rehabilitation and reconstruction in the State.

The National Institute of Disaster Management (NIDM), as a Statutory Body of the Government of India, has been mandated under the Disaster Management Act, 2005 for research, documentation and assisting the Government in policy-planning on all the aspects of disaster management. The Institute has made a commendable effort in documenting the disaster in all its dimensions to include the causes, impact, response, damage assessment and most importantly, the lessons learnt which have been outlined very lucidly covering pre-disaster perspective, preparedness, response and relief. The book, inter alia, covers reconstruction strategy, including valuable technical guidance for reconstruction. I compliment the NIDM and all its members who have contributed in developing this document in a very systematic and professional manner.

I am convinced that the book will add value to the existing literature on disaster management, particularly with the Indian perspective, and contribute towards an efficient disaster management in the days to come.

Sneh Lata Kumar
Secretary (Border Management)
Ministry of Home Affairs

10 November 2014.
New Delhi

राष्ट्रीय आपदा प्रबंधन संस्थान
(गृह मंत्रालय, भारत सरकार)
National Institute of Disaster Management
(Ministry of Home Affairs, Govt. of India)
5B, I.P. Estate, M.G. Marg, New Delhi - 110 002

nidm
Towards a disaster free India.....

प्रो. संतोष कुमार
कार्यकारी निदेशक
Prof. Santosh Kumar
Executive Director

PREFACE

In the recent year uncertainties have multiplied manifold when it comes to the event of natural disasters. It is evident from the previous disasters those occurred in the past and current disaster of Uttarakhand. Such phenomena are compelling us to think differently and find management solutions to it. Disasters are not a homogeneous category. Each disaster is different from other disaster. The current Uttarakhand Disaster 2013 is different from the previous one in 2010 and hence it has to be understood in the light of its divergent characteristics and features. Many lessons can be drawn by the disaster managers and at the same time lessons can also be drawn by the stakeholders dealing with development. Risks are generated over a period of time with various developmental interventions, where acknowledgements of risks are ignored, may be due to ignorance of the exposure to risks, is causing high economic losses and deaths.

The document "Uttrakhand Disaster 2013" has been a humble attempt by the faculty of National Institute of Disaster Management, who sincerely have tried to capture various learning points out of this disaster. The document has also given a profile of various disasters of which Uttarakhand is exposed to. Such information would be useful for the planners while planning development in the mountainous regions too.

Preparation of the document was initiated and supervised by my predecessor, Dr. Satendra, who also contributed towards its compilation and articulation. In addition, Dr. Anil Kumar Gupta, Dr. Surya Prakash, Maj. Gen. (Retd.) V.K. Naik and Shri Tapas Kumar Saha Roy, tried to capture insights from early warning to response, kind of losses the disaster created, and lessons learnt from the disaster. I compliment their efforts for bringing this document into shape.

On the basis of this document many further researchers can also be undertaken by different agencies/stakeholders as per their requirements. I am sure that in the context of climate change, disaster risk reduction and sustainable development commitments beyond 2015, this document would be a useful important reference. On the other hand, I am convinced that this could be utilised for training and capacity building programmes by different institutions as an authentic reference material.

(Santosh Kumar)

ACKNOWLEDGEMENTS

We would like to express our sincere gratitude to Shri M. Shashidhar Reddy, then Vice Chairman, National Disaster Management Authority (NDMA) and Shri V. K. Duggal, then Member, NDMA for their kind encouragement and support in the course of developing this publication on Uttarakhand Disaster 2013.

We are thankful to distinguished experts in Disaster Management, Dr. Muzaffar Ahmed, Member, NDMA and Shri Anil Sinha, Vice Chairman, Bihar State Disaster Management Authority for sharing their expert views during the national workshops organized by NIDM.

We are also grateful to Ms. Sneh Lata Kumar, Secretary, Border Management and Shri G. V. V. Sarma, Joint Secretary, Disaster Management in the Ministry of Home Affairs, Government of India, for their consistent encouragement, guidance, and assistance in bringing out of this book.

We would like to convey our sincere thanks to Dr. P. K. Mishra, Additional Principal Secretary (PMO), Prof. V. K. Sharma (Vice Chairman, Sikkim State Disaster Management Authority) and Dr. R. K. Bhandari (Former Director, CBRI) for their guidance, comprehensive review, suggestions/feedback, and recommendations. Special thanks are due to Shri Bhaskaranand and Dr. Piyoosh Rautela of Uttarakhand Government for providing valuable inputs as well as critical review, suggestions/feedback and recommendations for further improvement in terms of facts and figures in the book.

The authors also feel grateful to Prof. Chandan Ghosh, Dr. Surya Parkash, Dr. K. J. Anandha Kumar, Ms. Sreeja S. Nair, Dr. A. D. Kaushik and entire faculty of the NIDM for their kind cooperation, inputs and continuous support in this endeavour.

We would like to extend our appreciation for Shri S. K. Muttoo, Resident Commissioner (Rtd.), Govt. of Uttarakhand for his expert advice and critical review. His inputs are specially valuable as he was actively involved in the massive post-disaster response operations.

We are highly indebted to various experts and officials of the Central and State Governments, specially Padma Bhushan Shri Chandi Prasad Bhatt, Lt Gen N S Bawa, Shri S. R. Rathore, Shri I. S. Negi, Shri K. K. Razdan, Shri P. P. Srivastava, Shri Sanjay Agarwal, Shri Amit Sinha, Shri N. N. Pandey, Brig. (Dr.) B. K. Khanna, Dr. Y. V. N. Krishna Murty, Maj Gen Sushil Agarwal, AVM S.R.K Nair and Dr. S. C. Bhan for sharing information, knowledge and their expert views during the national workshop on the subject conducted by NIDM. We are also thankful to all the eminent delegates and specialist in disaster management, who were directly or indirectly, associated with the post disaster response operations, for sharing their experience and views.

We express our appreciation and gratitude to all the stakeholders, including State Government departments and Central Government agencies, and NGOs who contributed towards the accomplishment of this task.

Our very special thanks are due to Dr. S. P. Sati of H.N.B. Garhwal University, Srinagar, along with Shri Sunil Singh, Shri Ashutosh Jangwan, Shri Abhilekh Chandra Jagodi and Shri Abhinandan Badoni, research scholars of the University for their invaluable assistance in data collection.

We extend heartfelt thanks to Shri S. K. Tiwari, Librarian NIDM for extending necessary assistance in printing and Shri Shobhit Sharma for designing inputs. We also acknowledge the contribution of Ms Sunita Bhadauria and Shri Dipanker Guha in editing inputs. We are also grateful to Shri Rajinder Pall Sharma, Private Sectetary, NIDM for helping in the preparation of the book and also proof reading of the book along with Shri Saurav Kumar.

Lastly we would like to thank NIDM's administration, accounts, IT section, ED office staff and other supporting staff for their help at different times during the processing, preparation and printing of this book.

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Acronyms

ADB	Asian Development Bank
ALG	Advanced Landing Ground
ALH	Advanced Light Helicopter
AOR	Area of Responsibility
ASHA	Accredited Social Health Activist
ASI	Archaeological Survey of India
ASL	Above Sea Level
ATC	Air Traffic Control
ATF	Aviation Turbine Fuel
BDO	Block Development Officer
BIS	Bureau of Indian Standards
BMTPC	Building Materials & Technology Promotion Council
BRO	Border Roads Organization
BSF	Border Security Force
BSNL	Bharat Sanchar Nigam Limited
CAC	Central Air Command
CAPF	Central Armed Police Forces
CBO	Community Based Organization
CBRI	Central Building Research Institute
CEA	Central Electical Authority
CHC	Child Health Centre
CM	Chief Minister
CPWD	Central Public Work Department
CRC	Chief Resident Commissioner
CRPF	Central Reserve Police Force
CRRI	Central Road Research Institute
CWC	Central Water Commission
DCMG	Defence Crisis Management Group
DDMA	District Disaster Management Authority
DGMO	Director General of Military Operations

DIA	Disaster Impact Assessment
DIG	Deputy Inspector General
DM	District Magistrate
DMMC	Disaster Mitigation and Management Centre
DMP	Disaster Management Plan
DoT	Department of Telecommunications
DRM	Disaster Risk Management
DPR	Detailed Project Report
DRR	Disaster Risk Reduction
EAC	Eastern Air Command
EIA	Environmental Impact Assessment
EOC	Emergency Operation Centre
EWS	Early Warning System
FD	Fixed Deposit of Money in Bank
FEMA	Federal Emergency Management Agency
FGD	Focussed Group Discussions
GDP	Gross Domestic Product
GHG	Green House Gases
GIS	Geographical Information System
GLOF	Glacial Lake Outburst Flood
GMVNL	Garhwal Mandal Vikas Nigam Limited
GOC	General Officer Commanding
GOI	Government of India
GoU	Government of Uttarakhand
GSI	Geological Survey of India
HEP	Hydro Electric Projects
HH	House Hold
HQ	Head Quarter
HRVC	Hazard, Risk, Vulnerability and Capacity
HVCRA	Hazard, Vulnerability, Capacity and Risk Assessment
IAF	Indian Air Force
IBM	International Business Machines
ICS	Incident Command System

IRC	Indian Road Congress
IDRN	India Disaster Resource Network
IDS	Integrated Defence Staff
IDSP	Integrated Disease Surveillance Programme
IG	Inspector General
IHQ	Integrated Headquarters
IIRS	Indian Institute of Remote Sensing
IIT	Indian Institute of Technology
IMD	Indian Meteorological Department
INCP	Integrated National Command Post
INR	Indian Rupees
IOC	Initial Operational Capability
IRS	Incident Response System
ISRO	Indian Space Research Organization
ITBP	Indo-Tibetan Border Police
ITI	Industrial Training Institute
JRDNA	Joint Rapid Damage and Needs Assessment
KAP	Knowledge Aptitude and Practices
LHZ	Landslide Hazard Zonation
LPCD	Litres per Capita Per Day
LT	Low Tension
MARCOS	Marine Commandos
MBT	Main Boundary Thrust
MCT	Main Central Thrust
MDR	Major District Roads
MEA	Ministry of External Affairs
MHA	Ministry of Home Affairs
MLD	Million Litres Per Day
MLH	Medium Lift Helicopter
MoD	Ministry of Defence
MoEFCC	Ministry of Environment, Forests and Climate Change
MRTs	Mountain Rescue Teams
MSK	Medvedev Sponheuer Karnik (Scale of Seismic Intensity)

MW	Megawatts
NCMC	National Crisis Management Committee
NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NDRF	National Disaster Response Fund
NEC	National Executive Committee
NGO	Non Government Organization
NGT	National Green Tribunal
NH	National Highway
NHAI	National Highways Authority of India
NIDM	National Institute of Disaster Management
NIMHANS	National Institute of Mental Health and Neuro Sciences
NRHM	National Rural Health Mission
NRSA	National Remote Sensing Agency
NRSC	National Remote Sensing Centre
NTFP	Non Timber Forest Products
NWFC	National Weather Forecasting Centre
ODR	Other District Roads
OGE	Out of Ground Effect
OP	Operation
PHC	Primary Health Centre
PMGSY	Pradhan Mantri Gram Sadak Yojana
PMNRF	Prime Minister's National Relief Fund
PWD	Public Works Department
R&D	Research & Development
RAT	Reconstruction Assessment Team
RBM	River Bed Mining
RCC	Reinforced cement concrete
RISAT	Radar Imaging Satellite
RWFC	Regional Weather Forecasting Centre
SAC	Southern Air Command
SAD	State Allopathic Dispensary
SDMA	State Disaster Management Authority

SDRF	State Disaster Response Fund
SDRF	State Disaster Response Force
SEC	State Executive Committee
SEOC	State Emergency Operation Centre
SH	State Highway
SHQ	Sector Head Quarters
SLWM	Solid & Liquid Waste Management
SMS	Short Messing Service
SOPs	Standard Operating Procedures
SSB	Sashastra Seema Bal
TEC	Techno Economic Clearance
UAV	Unmanned Aerial Vehicles
UJVNL	Uttaranchal Jal Vidyut Nigam Limited
UK	United Kingdom
UN	United Nations
UNDMT	United Nations Disaster Management Team
UNDP	United Nations Development Programme
UPCL	Uttarakhand Power Corporation Limited
UREDA	Uttarakhand Renewable Energy Development Agency
USA	United States of America
USAC	Uttarakhand Space Application Centre
VPN	Virtual Private Network
VR	Village Roads
WAC	Western Air Command
WASH	Water Sanitation and Hygiene
WIHG	Wadia Institute of Himalayan Geology
WII	Wild Life Institute of India
WWF	World Wide Fund for Nature

1 Introduction

1

INTRODUCTION

Uttarakhand is an Indian Himalayan State known for its rich spiritual and religious tourism, ecological richness & diversity, and cultural ethos rooted in traditions, but it is also known for growing frequency and intensity of natural disasters, and for its fragility of ecological and geological systems. Consisting mostly of uplifted sedimentary & metamorphic rocks and tectonically very active, the region is vulnerable to natural disasters. Due to its geo-climatic, ecological and socio-economic settings, Uttarakhand is one of the most disaster prone States of the country.

Natural hazards like earthquakes, landslides, avalanches, cloudburst, hailstorms, glacial lake outburst floods (GLOFs), flash floods, lightning, forest fires, etc. have been known to cause major losses to life, property, resources and ecosystems in the region and thereby affecting its process of economic development. In addition to natural phenomenon, various human activities like - unscientific development & land-use pattern, unwarranted changes of landscape, ecosystem structure & functions, forest degradation & deforestation, increasing pressure of tourism, waste disposal - have also contributed to the vulnerability of the region to hazards. Development of hydropower projects, construction of roads and buildings, river bed mining, are some of the examples, which have direct or indirect but significant impact on landscape, land-use and natural eco-geological systems, resulting into undesired influence on factors governing vulnerability to natural hazards.

In the month of June 2013, the region suffered its worst disaster in its living memory with huge loss of lives and wide spread destruction. The disaster coincided with the peak tourist and pilgrimage season, considerably enhancing the number of the

causalities with adverse impact on the immediate rescue and relief operations. The entire region of the State was hit by 'heavy' to 'very heavy' rainfall, possibly due to the fusion of Westerlies with the Indian Monsoonal cloud system, resulting into flash floods and landslides over a wide area. The districts of Bageshwar, Chamoli, Pithoragarh, Rudraprayag and Uttarkashi were the worst affected. Large populations in several areas were cut off across the State and suffered due to shortage of essential commodities.

The nature's fury was most pronounced in the Mandakini valley of the Rudraprayag district. Torrential rains coupled with the collapse of the Chorabari Lake led to flooding at the Kedarnath Shrine and the adjacent areas of Rambara, Agastyamuni, Tilwara, and Guptkashi. Other pilgrimage centers in the region, including Gangotri, Yamunotri, and Badrinath, which are visited by thousands of devotees during the summer season, were also affected. People were stranded for days to weeks at isolated locations such as Harsil, Roopkund and Hemkund Sahib. Over one lakh people were stuck in various parts of the State owing to blockages by damaged roads, landslides, flash flood induced debris and absence of communication.

The impact of the disaster was unfathomable for the local population as well as the pilgrims. The magnitude and intensity of the disaster took the State administration and the Central Government by surprise. The administration launched a huge rescue and relief operation immediately with the assistance of the Centre, accomplishing one of the biggest rescue and relief operations in which more than one lakh persons were evacuated to safe places. The Army, the IAF, Para Military Forces, the State administration and NDRF worked tirelessly to bring some comfort to the suffering population.

The disaster termed as *Himalayan Tsunami* by the media, caused wide spread loss of lives and damage to infrastructure, property and environment with resultant impact on the livelihoods and local economies. More than nine million people were affected by the episodes of flash floods. Five districts, namely, Bageshwar, Chamoli, Pithoragarh, Rudraprayag and Uttarkashi were worst affected. As per the report made available by the State Government on 09 May 2014, a total of 169

people died and 4,021 people were reported missing (presumed to be dead). About 4,200 villages were affected; 11,091 livestock were lost and 2,513 houses were completely damaged. Large number of tourists and local inhabitants were stranded in the difficult mountain terrain of the upper regions of the Himalayas. It is also noteworthy that since tourists and pilgrims were in huge number during that period, most of the fatalities were natives of other States and Union Territories.

While the main cause of casualties was physical exposure to flash flood, the harsh weather conditions, i.e., continuous rainfall, biting cold and timely non-availability (of food, potable water, shelter, warm clothes, etc.) were also responsible for the grim distress to pilgrims. There was extensive damage to housing, both in urban and rural areas, because settlements were mostly concentrated along the rivers. Damage to public buildings resulted in severe disruption of basic services such as food, shelter, health, education, women & child care, etc.

Flash floods with heavy sediment load caused intense erosion of the river banks which washed away large sections of roads and a large number of bridges at many places. Road connectivity to thousands of villages in the affected parts of the State was lost and the areas remained disconnected and isolated for weeks. A large number of vehicles were washed away, buried under debris, fell off the hills, or were stranded at cut-off locations.

The urban infrastructure in majority of the towns was seriously at risk. Flash floods caused damage to water supply systems in Chamoli, Rudraprayag, Pauri, Tehri, and Uttarkashi urban areas. Agriculture/horticulture and tourism are major contributors to the State's economy. More than two lakh people engaged in agriculture, horticulture and animal husbandry are reported to have lost their livelihood due to the disaster. Tourism, which is one of the fastest growing industries and a major driver of economic growth and livelihood promotion in the State, was hit very badly. Thousands of households in the five worst affected districts were dependent on the tourism for their livelihood. As a result of the disaster, a large number of the petty traders, hotel & restaurant owners and bus & taxi operators lost their livelihoods. The impact of disaster in region included damage to the routes to the holy pilgrimage circuit of the *Char Dham Yatra*. The loss of livelihoods, particularly in the tourism sector, has also posed a threat of forced migration in the region.

With heavy damage to the on-going Hydro Electric Power projects and the existing power distribution system, the disaster has taken a heavy toll in the energy sector as well. In addition, there was widespread damage in the Forest sector where a loss of forest area of about 80 hectares along river courses is estimated. Almost 1,000 km length of forest roads and about 2,500 km of bridle paths are reported to be damaged.

Wide spread damage and destruction to infra-structure and housing, and most importantly the loss of livelihoods, pronounces for long-tedious ways ahead for recovery including reconstruction, rehabilitation and future risk reduction. While the Centre and the State Governments have initiated prompt actions, documentation of the disaster and related response management actions, in an objective manner, are necessary to help introspect and analyze the causes of tragedy and for drawing lessons to improve contemporary disaster management structures, mechanisms and practices.

In order to comprehend the causes, impact of disasters and lessons to be drawn for future, NIDM undertook a post-disaster survey by engaging teams of qualified professionals and one such team visit was led by the Executive Director himself. The survey results essentially reinforced the understanding that planning and implementation of developmental activities need to judiciously consider environmental sensitivities, current and projected state of impacts on environment and natural hazards, underlying factors of vulnerability, and relationship of these factors with people's livelihood, local capacities of risk management and preparedness to deal with disasters.

The disaster caused huge devastation to almost all developmental facets in the State, which needs a reconstruction strategy that takes care of high vulnerability of mountain communities and land to natural hazards in the backdrop of ecological fragility, environmental impacts, livelihood resilience and local economic sustainability issues. The elements of disaster risk reduction need to be very innovatively woven into all the development and reconstruction plans of the State at a strategic level. These could inter alia include supporting sustainable agricultural, pasture and forestry practices and integrating local environmental knowledge and community memories in disaster risk reduction strategies. The

impact of post-disaster reconstruction on affected communities' livelihoods and on their resilience to future disasters will remain a major issue in all developmental activities.

In the backdrop of region's vulnerability to heavy rainfall resulting in extensive damages along the river courses and widespread landslide incidences, there is a need to follow best practices in the landslide stabilization techniques including ecological and bio-engineering solutions. Apart from the hazard mapping and assessments, real time monitoring, evaluating the economic impacts of landslides, training and most importantly public awareness and education, the Landslides Mitigation Strategy needs to focus on developing a predictive understanding of landslide processes and triggering mechanisms.

The reconstruction activities post-disaster in the affected areas should be driven by well considered policy initiatives duly backed with legislation and public awareness campaign. This is particularly important for development of religious tourism, aspects of environment safeguards, natural resources and long-term livelihood security. Issues related to hazard forecasting, including involvement of scientific community with adequate funding for R&D, need to be addressed on priority.

It is axiomatic that the reconstruction in disaster affected Uttarakhand region will have to be a well planned, comprehensive state-led effort built upon local capacity with “build back better” approach. This needs to be well integrated with the efforts of recovering local economy, livelihood regeneration and ecosystem services resilience. It is of utmost importance that community emerges as the most vibrant stakeholder in the reconstruction plans with creation of structures empowered for objective monitoring and critical review of the execution of the plans.

The State Government has since initiated comprehensive reconstruction and rehabilitation programmes assisted by the Central Government and the World Bank. It is important that this unprecedented disaster is indeed turned into an opportunity for sustainable and safer development by the concerted efforts and cooperation of all the stakeholders.

2 Hazard-Vulnerability Profile of the Region and Causes of the Disaster-2013

2

HAZARD-VULNERABILITY PROFILE OF THE REGION AND CAUSES OF THE DISASTER-2013

2.1 Background

The Himalayan mountain range covers widespread geographical area of India, across the States of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Assam, and parts of West Bengal. It extends from the Hindu Kush in the North West to Myanmar in the South East, covering a distance of about 2400 km. The Himalayas are among the youngest mountain ranges in the world. Consisting mostly of uplifted sedimentary and metamorphic rocks and tectonically very active, the region is extremely vulnerable to natural disasters, including floods and landslides.

The Himalayan State of Uttarakhand is located between 28° 43' - 31° 27' N latitude and 77° 34' - 81° 02' E longitude and is divided into two divisions - Garhwal and Kumaon (Figure 2.1) and 13 districts. It consists of 76 towns and 95 development blocks. Dehradun, the largest city in the region, is the capital of Uttarakhand. The State includes 320 km long stretch of the mountains between the Kali River forming the Indo-Nepal border in the East and the Tons-Pabbar valleys forming the eastern border of the Himachal Pradesh in the West.

The geomorphology of the State is defined by the Himalayas being completely land locked. The State has a wide range of geomorphic features like cliffs, rocky slopes, waterfalls, major and minor ridges, river valleys, highly dissected denudational hills, moderate and low dissected denudational hills, river terraces, and various

fluvial geomorphic features like point bar, meandering scars, and natural levees. The hill area of the State is sensitive towards mass wasting[1]. In the foot hills, the *Terai* and *Bhabar* areas of the State are prone to flooding and water logging.

Figure 2.1: Map of Uttarakhand

Several rivers which are lifelines to one of the most densely populated areas in the world (the Gangetic Plains of India) originate in this region (Figure 2.2). Rivers Ganga (comprising Alaknanda and Bhagirathi) and Yamuna, which originate at Gangotri and Yamunotri respectively, are the most important rivers of the region. Another mighty river that brings misery when in its spate is the river Kali on the eastern border of the State.

Based on the topography of the area and its geographical location, the temperature varies throughout the region. The average temperature in the State varies from -1.7°C to 42°C. The State is bestowed with a relatively high average annual rainfall of 1229 mm[2]

Figure 2.2: Drainage map of Uttarakhand[3]

The ecology of Uttarakhand mostly comprises of forest covers and grasslands. A large variety of flora and fauna found here are usually the rarest species in the world. The diversity in topography, climate, vegetation, life, culture, etc. depicts varied and complex characteristics of the region and therefore, the State of Uttarakhand has rich cultural, physical and favourable ecological support for wildlife sanctuaries and endangered plant and animal species.

Due to the hilly terrain, the roads are the only means of surface communication.

The national railway network extends to rail heads at Dehradun, Rishikesh, Ramnagar, Kotdwar, Kathgodam and Tanakpur (Figure 2.3). The total road length in the region is about 31,929 km. The trunk roads or arterial roads in the State are maintained by the Border Roads Organization (BRO) while other roads are maintained by the Public Works Department (PWD). The roads encompass 1,151 km of national highways; 3,788 km of State highways; 3,290 km of major district roads; 2,945 km of other district roads and 15,402 km of village roads.

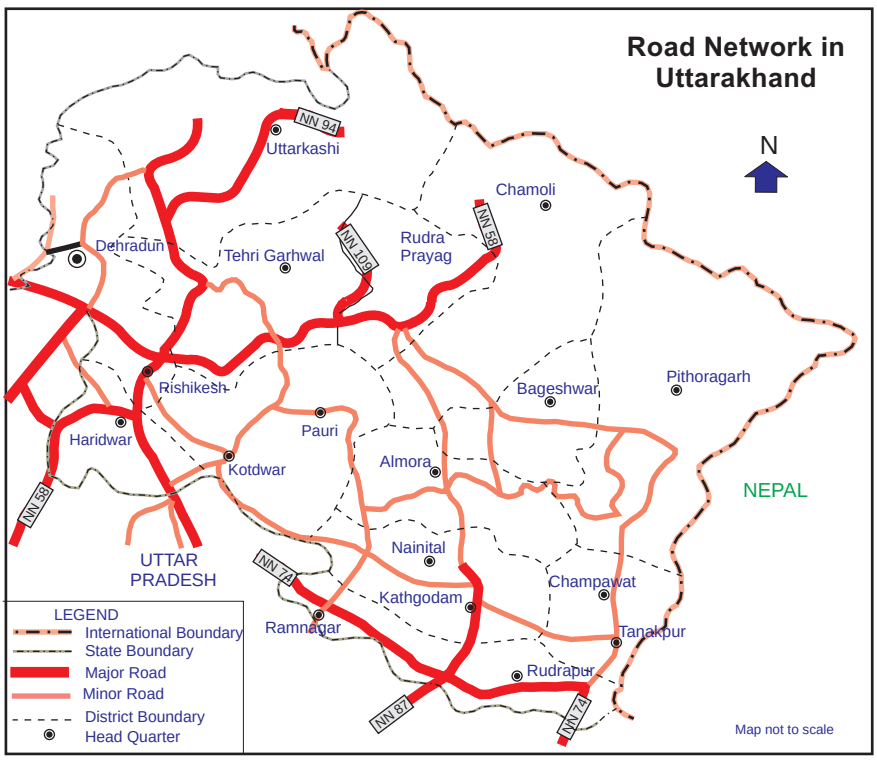

Figure 2.3: Major Road Network in Uttarakhand[4]

2.2 Vulnerability to Natural Disasters

Natural hazards in Uttarakhand are pronounced due to its tectonic activity, lithological, structural and ecological settings, topography and changing landscapes owing to various natural and anthropogenic activities. Natural hazards like earthquakes, landslides, land subsidence, slope failures, rockfall, avalanches, cloudbursts, hailstorms, Glacial Lake Outburst Floods (GLOF), floods, flash floods,

lightning, forest fires, etc. are frequent in Uttarakhand causing loss of life and property from time to time.

There has been a spurt of development oriented activities following formation of the State. There has been fast pace construction of roads and buildings and setting up of hydro electric projects. Agriculture and horticulture is facing the challenge of disinterest from native people, and tourism being projected as the major source of livelihood in the hills gained boom after the formation of Uttarakhand as separate State. This has necessitated construction and development of suitable tourist amenities and services. Side effects of these activities are known to have considerably amplified the intensity of naturally occurring disasters and their impacts.

2.3 Disasters in Uttarakhand

2.3.1 Earthquakes

As per earthquake zonation map of India, the entire region of the State can be covered into two zones, Zone IV and Zone V[5]. The region experienced many earthquakes of small and large scale with their epicenters located within the Himalayan region (Figure 2.4). The State has witnessed two major earthquakes in the recent past, the Uttarkashi earthquake in 1991 and the Chamoli earthquake in 1999. Nearly 768 people died in Uttarkashi and 106 died in the Chamoli earthquake[6]. The districts of Bageshwar, Chamoli, Pithoragarh, Rudraprayag and Uttarkashi, which were severely affected in the 2013 flash floods fall within the Seismic Zone V[7].

As shown in the map (Figure 2.4), four of the thirteen districts of the State (Pithoragarh, Chamoli, Bageshwar and Rudraprayag) entirely fall in Zone V (representing damage risk of ≥ IX on MSK scale), whereas other five districts (Uttarkashi, Tehri-Garhwal, Pauri, Almora and Champawat) fall partially in Zone IV and partially in Zone V (damage risk of VIII on MSK scale) and the rest (Dehradun, Haridwar, Nainital and Udham Singh Nagar) fall in the Zone IV of earthquake risk levels.

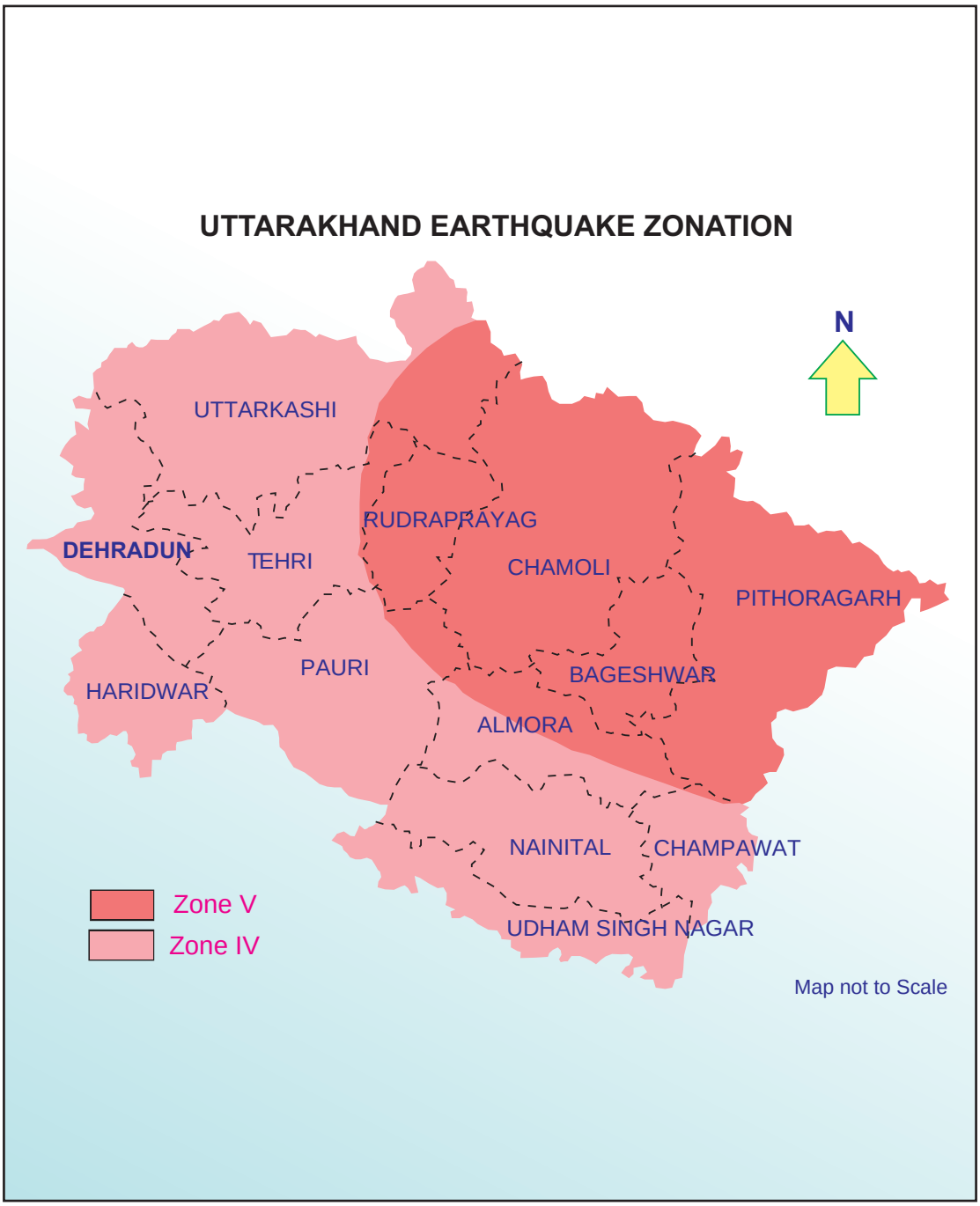

Figure 2.4: Uttarakhand earthquake hazard zonation map[8]

Region's vulnerability to earthquakes is characterized by the fact that during the last century, this region has experienced 11 earthquakes of magnitude greater than 6.0 on the Richter scale[9]. As per the India Meteorology Department, there have been 65 earthquakes of varying intensity since 1803 in the state and nearby region. (Table 2.1).

Table 2.1: Earthquakes of Uttarakhand[10, 11]

S. No.	Date of occurrence	Magnitude	Affected area
1	1st September 1803	9.0	Badrinath
2	1809	9.0	Garhwal
3	26 May 1816	7.0	Gangotri
4	25 July 1869	6.0	Nainital
5	28 October 1916	7.5	Dharchula
6	28 October 1937	8.0	Dehradun
7	27 July 1966	6.3	Kapkot, Dharchula
8	28August 1968	7.0	Dharchula
9	29 July 1980	6.5	Dharchula
10	20 October 1991	6.6	Uttarkashi
11	29 March 1999	6.8	Chamoli
12	1 February /2006	5.2	Indo - China Border
13	14 March 2006	5.0	Indo - China Border
14	27 October 2006	3.8	Bageshwar
15	31 March 20006	3.1	Chamoli
16	5 August 2006	5.0	Indo - Nepal Border
17	26 September 2006	4.1	Indo - Nepal Border
18	27 October 2006	3.8	Bageshwar
19	5 February 2007	3.5	Indo - Nepal Border
20	27 March 2007	3.2	Uttarkashi
21	22 July 2007	5.0	Uttarkashi
22	7 August 2007	3.5	Uttarkashi
23	3 November 2007	2.7	Uttarkashi
24	25 January 2008	3.5	Rudraprayag
25	13 August 2008	3.6	Bageshwar
26	4 September 2008	5.1	Indo -Tibet Border
27	25 February 2009	3.7	Uttarakhand
28	18 March 2009	3.3	Uttarkashi
29	15 May 2009	4.5	Chamoli

30	27 August 2009	3.9	Uttarakhand
31	18 September 2009	3.4	Uttarakhand
32	21 September 2009	4.7	Uttarkashi
33	3 October 2009	4.3	Bageshwar
34	11 January 2010	3.9	Pithoragarh
35	22 February 2010	4.7	Bageshwar
36	3 May 2010	3.5	Uttarakhand
37	31 May 2010	3.6	Almora
38	22 June 2010	4.7	Pithoragarh
39	10 July 2010	4.1	Almora
40	14 March 2011	3.3	Chamoli
41	20 June 2011	4.6	Chamoli
42	24 June 2011	3.2	Indo - Nepal Border
43	4 July 2011	3.4	Chamoli & Almora
44	21 September 2011	3.1	Uttarkashi
45	24 September 2011	3.0	Uttarkashi
46	6 September 2011	3.8	Indo - China Border
47	20 November 2011	3.2	Uttarkashi
48	14 December 2011	3.2	Chamoli
49	9 February 2012	5.0	Uttarkashi
50	10 May 2012	3.9	Chamoli
51	1 June 2012	3.7	Chamoli
52	26 October 2012	3.5	Chamoli
53	12 November 2012	2.5	Uttarkashi
54	15 November 2012	3.0	Pithoragarh & Bageshwar
55	26 November 2012	2.8	Bageshwar
56	27 November 2012	4.8	Uttarkashi
57	30 January 2013	2.6	Bageshwar
58	11 February 2013	4.3	Uttarkashi
59	17 February 2013	3.2	Uttarkashi
60	25 February 2013	3.1	Uttarkashi
62	6 March 2013	3.2	Indo - Nepal Border
63	24 March 2013	2.9	Indo - Nepal Border
64	6 April 2013	4.3	Rudraprayag
65	5 September 2013	3.5	Uttarkashi

2.3.2 Landslides

During the periods of rainfall, landslides, slope failures or land subsidence is common in Uttarakhand hills. These are known to cause loss of human and animal lives, damage to infrastructure like roads and buildings and destruction of agriculture and ecosystems. These are also known to aggravate, if environmental aspects of developmental activities are not adequately addressed. As per Central Water Commission, the possibilities of the landslides/slips can be avoided or considerably reduced by proper implementation of catchment area treatment plan including stabilizing of landslides/slips prone areas, reservoirs, rim treatment works, plantations etc.

Landslides are particularly common in Uttarakhand along two zones lying in close proximity of two major tectonic discontinuities - Main Boundary Thrust (MBT) and Main Central Thrust (MCT)[12] (Figure 2.5).

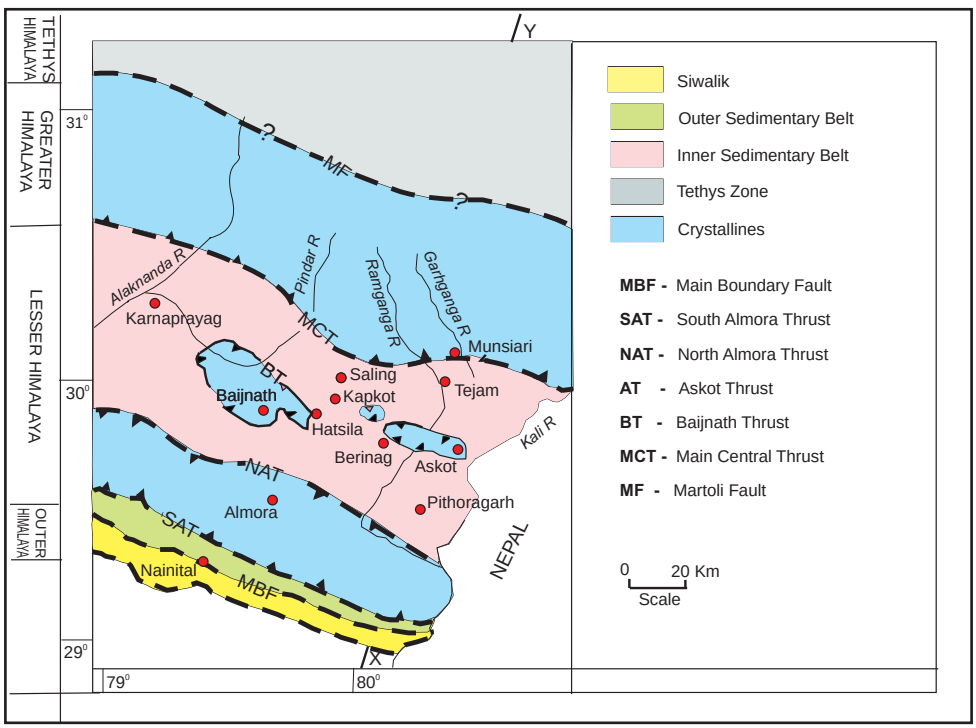

Figure 2.5: Subdivisions of Himalayas and associated thrust planes in Uttarakhand[13]

Many landslides have occurred in Uttarakhand in the past (Table 2.2). During August 1998, 103 people died in landslides which had struck in Madhmaheshwar and Kali Ganga valley[14]. In 2001, approximately 20 people died in landslides in Phata and Gad area of Uttarakhand. About 16 people were killed in another landslide event on 5 July, 2004 that took place in Badrinath. Landslide hazard zonation map of the State showing vulnerable areas is given in Figure 2.6.

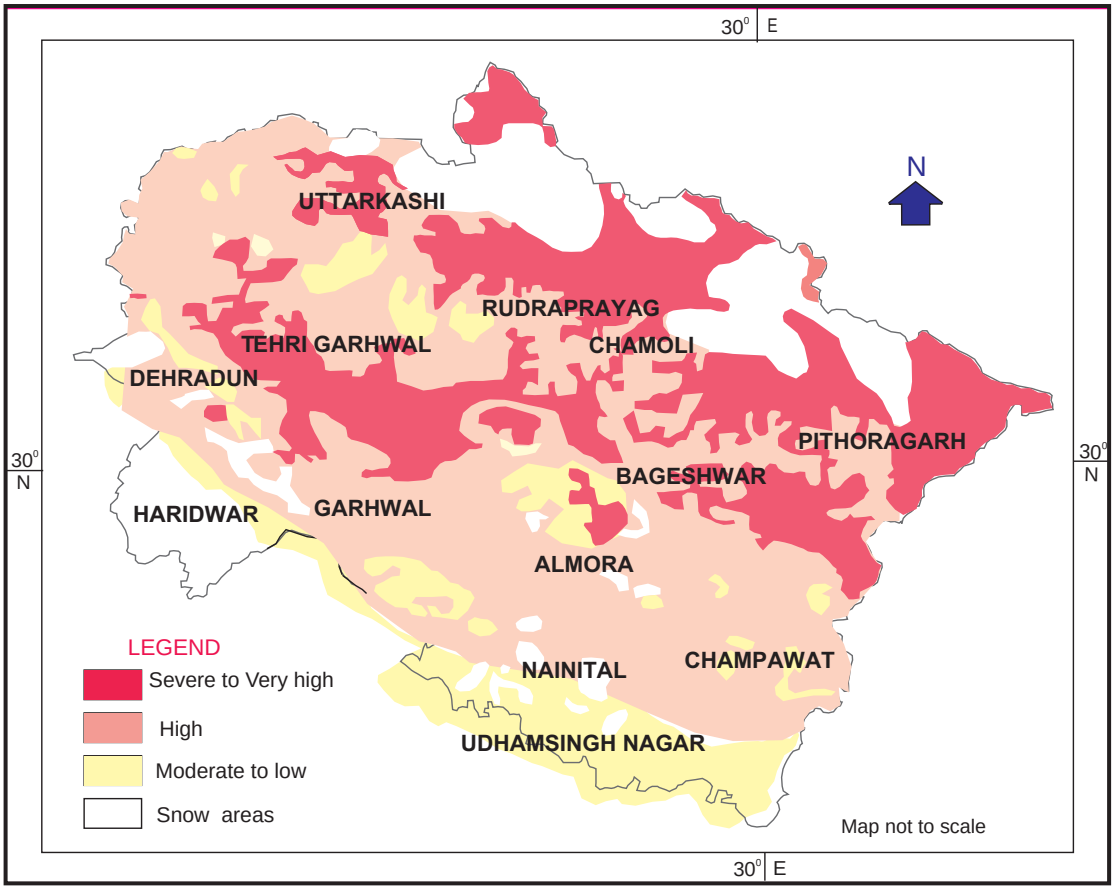

Figure 2.6: Landslide zones of Uttarakhand[15]

Table 2.2: Major landslides in Uttarakhand[16]

Date / Year	Location	Remarks
1867 and 1880	Nainital	Two major landslides on the Sher-ka-Danda slope in Nainital. The 1880 landslide took place due to rainfall and an earth tremor, destroying buildings, and permanently filled a portion of the Naini lake.
1893	Alaknanda	Floods in the Birehi Ganga river near its confluence with the Alaknanda river triggered landslides causing major blockage of the river with a 10-13 m afflux. A girder bridge was bypassed and another one was destroyed.
1968	Rishi-Ganga	The Rishi Ganga river in Garhwal was blocked due to landslide at Reni village.
July 1970	Patal Ganga,	The Patal Ganga (a tributary of the Alaknanda river) was choked and a reservoir was created. The bursting of this choked reservoir resulted in flash floods in the Alaknanda river, triggering many landslides.
1971	Kanauldia gad	A major landslide on the bank of the Kanauldia Gad, a tributary of the Bhagirathi river upstream from Uttarkashi formed a debris cone that impounded water to a height of 30 m. Its breaching caused flash floods downstream.
August 1978	Uttarkashi	The Kanauldia Gad, a tributary joining the Bhagirathi river upstream from Uttarkashi in the Uttarakhand formed a debris cone across the main river, impounding the river to a height of 30 m. Its breaching caused flash floods, creating havoc. A 1.5 km long and 20 m deep lake was left behind because of the partial failure of the landslide dam.
1920, 1952, 1963, 1964, 1965, 1968, 1969, 1970, 1971, 1972 and 1985	Kaliasaur	Kaliasaur is one of the most persistent and regularly occurring landslides areas, located along the Rishikesh-Badrinath road. Landslides in this region result into frequent road blockage and land damage.
August 1998	Okhimath	Sixty-nine people were killed due to several landslides near Madhmaheshwar valley. The landslides caused huge devastation in villages.
18 August 1998	Malpa, Kali river	More than 210 people were killed. The heap of debris created was about 15 m high. The village was wiped out in the event.
24 September 2003	Varunavat Parvat, Uttarkashi	Incessant rains triggered massive landslide in the area, causing the burial of numerous buildings, hotels, and government offices located at the foot of the hill slopes.
5 July 2004	Badrinath, Chamoli	Sixteen persons killed, 200 odd pilgrims stranded, 800 shopkeepers and 2,300 villagers trapped as cloudburst triggered massive landslides washed away nearly 200 m of road on the Joshimath-Badrinath road cutting off Badrinath area.

29-30 June 2005	Govindghat, Chamoli	A cloudburst/landslide occurred in which huge quantities of debris and rock boulders were brought down along a seasonal *nala*. Eleven people were killed and property lost.
6 September 2007	Village Baram/Sialdhar, Dharchula, Pithoragarh	A landslide due to excessive rainfall resulted in 15 fatalities and loss of livestock.
2008	Amru Band	Total 17 people were killed[17], huge damages to roads and houses.
8 August 2009	Berinag-Munsiyari road, Pithoragarh	Forty three people died[18] due to landslide triggered by cloud burst.
18-21 September 2010.	Ganga- Alaknanda valley	Nearly 220 people died[19], 170 major and minor roads severely damaged.
14 September 2012	Okhimath, Rudraprayag	Sixty eight people killed in the landslides[20],which caused extensive damages to the buildings, agricultural lands, and roads at several places[21].

2.3.3 Avalanches

Generally, avalanches are common in Himalayan region with altitude more than 3500 m and slope more than 30 degrees. Convex slopes are generally more prone to avalanches. North facing slopes are known to have avalanches in winter, whereas south facing slopes usually get them during spring time. The holy shrines of Hemkund, Badrinath, Kedarnath, Yamunotri and Gangotri come under avalanche prone areas. Main avalanches occurred in Uttarakhand in the recent past are shown in Table 2.3.

Table 2.3: Major avalanches in Uttarakhand

Date / Year	Location	Remarks
June 2008	Gomukh Glacier near Gangotri, Uttarkashi	One person died and 9 injured[22].
June 2008	Hemkund Shahib, Chamoli	Six died and more than 12 people injured[23].

September 2008	Kalindi-Badrinath track in the Garhwal Himalaya, Chamoli	Three persons were killed and 37 persons were rescued[24].
21 September, 2010	Ghastoli, Chamoli	Two army officers were killed[25].
12 June 2013and 1 July 2013	Kedarkharak, Uttarkashi Uttarkashi District	One person killed[26]. Three Army personnel injured and 1 killed[27].

2.3.4 Floods and Flash Floods

With rainy season normally from late April to September the average rainfall of the Uttarakhand State is 1229 mm. Periods of high rainfall from July to September, result in flooding low lying areas and erosion of land. Increase of soil erosion in hilly areas has reduced the carrying capacity of rivers.

Flash Floods are very common hydro-meteorological hazards which occur due to excessive or high rainfall combined with rapid snowmelt, bursting of natural or constructed dams, cloudburst, etc. These floods are devastating because of the high velocity of water with huge energetic capacity to carry away everything on its way. A list of major flash flood events from 1989 to 2011 along with damage is given in the Table 2.4.

Table 2.4: List of major flash flood events in the Uttarakhand[28]

Date	Locations	Damage
05-09-1989	Karanprayag, Chamoli	Three people died and 2 injured
26-12-1991	Uttarkashi	Three people died
30-07-1994	Chaukhutia , Almora	Four people died
02-08-1997	Near Neelkanth, Haridwar	Eighteen people died
17-07-2001	Near Meykunda, Rudraprayag	Twenty seven people died
20-07-2003	Didihat, Pithoragarh	Four people died
21-05-2004	Kapkot, Bageshwar	Three people died
09-06-2004	Kapkot, Bageshwar	Three people died

21-07-2005	Vijaynagar, Rudraprayag	Four people died
13-08-2007	Didihat, Pithoragarh	Four people died
25-07-2009	Joshimath, Chamoli	Three people died
2009	Munisyari, Pithoragarh	Forty Three lives lost due to massive cloudburst induced flash flood[29]
19-07-2010	Kot, Pauri	Six people died
20-07-2010	Khatima, Rudrapur, Udham Singh Nagar	Three people died
31-07-2010	Dehradun	Five people died and 2 missing
18-08-2010	Dhari, Nainital	Thirteen people died and 3 injured
24-08-2010	Jaspur, Udham Singh Nagar	Four people died
08-09-2010	Karanprayag, Chamoli	Three people died
11-09-2010	Nyalgarh, Pauri	Three people died
18-09-2010	Belbandgoth, Champawat	Four people died
18-09-2010	Jwalapur Kasim, Haridwar	Five people died and 2 injured
20-09-2010	Dhari, Nainital	Five people died and 12 injured
22-09-2010	Kot, Pauri	Five people died
06-05-2011	Raipur, Dehradun	Three people died
15-08-2011	Tuneda, Bageshwar	Twenty one people died and 1 injured
03-08-2012	Asi Ganga Valley, Uttarkashi District	The worst affected areas were Gangotri, Sangam Chatti and Bhatwari. About 7,389 people from 1,159 families in 85 villages were affected. Nearly 28 people were killed in flash floods and landslides[30.]

2.3.5 Cloudbursts

Cloudburst is an extreme amount of precipitation, sometime with hail and thunder storm, which normally lasts for minutes but can also cause flash floods. Occasional cloudbursts in the region have resulted in flash floods and breaching of river banks, as listed in Table 2.5.

Table 2.5: List of major cloudbursts in Uttarakhand[31]

Year	Location	Damages
2002	Khetgaon	Four people died
2004	Ranikhet	One person died
2007	Pithoragarh and Chamoli	Twenty three people died
2008	Pithoragarh	One person died
2009	Munsiyari Tehsil, Pithoragarh	Forty three people died
18 August 2010	Kapkot, Bageshwar	Eighteen school children were buried alive and 8 injured due to massive cloudburst
21 July 2010	Almora	Thirty six people died in cloud burst induced flash flood
13 September 2012	Chwanni, Mangoli and Kimana villages of Okhimath block in Rudraprayag	Completely inundated over Four villages and eroded two more villages[32]

2.3.6 Soil Erosion

Soil erosion by water, poses a serious threat to the people of Uttarakhand, which is drained by a large network of river systems mainly Ganga, Yamuna and Kali river systems and experiences high rainfall during monsoon.

The erosion rate in Uttarakhand has amplified due to various anthropogenic reasons. Uncontrolled biotic pressure on forest areas like unscientific agricultural activities and overgrazing, agricultural expansion and mining activities, combined

with environmental effects of construction activities, housing and transportation, etc. are likely attributes for increased soil erosion in the hilly terrains of Uttarakhand. Changed pattern of rainfall during monsoon in the form of bunching of precipitation events has also contributed to increased run-off resulting into soil and river bank erosion. Increase in soil erosion has resulted in deposition of silt and sediment in river beds making them shallow and reducing their carrying capacity.

2.3.7 Forest Fire

Due to various factors including the vulnerability of vegetation strands and specifically particular species, changing climatic variability and temperature ranges, inadequate fire-fighting equipment and manpower, the forests of Uttarakhand are badly affected by forest fires almost every year. Besides the direct damage, the other losses induced by these fires include loss of soil nutrients and fertility, soil erosion, drying up of water resources and loss of biodiversity. These fires also cause a change in the microclimate of the region by modifying soil moisture balance and increasing evaporation. In the hills of Uttarakhand, usually the fire incidents occur between the months of April to June.

2.4 Causes of Vulnerability

2.4.1 Natural Causes

Natural causes for the disasters are deep-rooted within the earth's crust. It is the natural geological setting of the region which makes it susceptible and prone to disasters. Though, the whole of the Himalayan region is very sensitive due to complex geological factors, the State of Uttarakhand is comparatively more prone to disasters. The various tectonic features like thrust, faults, shear zones, etc. are very common in the Uttarakhand part of the Himalayas. The major tectonic features of Himalayas - Himalayan Frontal Fault, Main Boundary Thrust, Main Central Thrust, and Trans Himalayan Thrust - are the main characteristic of the region making it tectonically more active and unstable (Figure 2.7). According to the Plate Tectonic Theory, the ever increasing pressure of the Indo-Australian plate is

activating these thrusts and other associated tectonic features, making the region geologically unstable, fragile and prone to natural hazards. The instability of Uttarakhand is further increased by the presence of one more tectonic feature - Delhi-Haridwar ridge. This ridge beyond Delhi is submerged below alluvium and penetrates below the Himalayan rocks. As this ridge is lying on Indo-Australian plate and this plate is moving northward, it is mounting continuous pressure on Himalayan belt in Uttarakhand. To some extent, collision of these two mountain belts - Delhi-Haridwar and Himalaya - is also responsible for making the Uttarakhand region more unstable and susceptible to natural hazards.

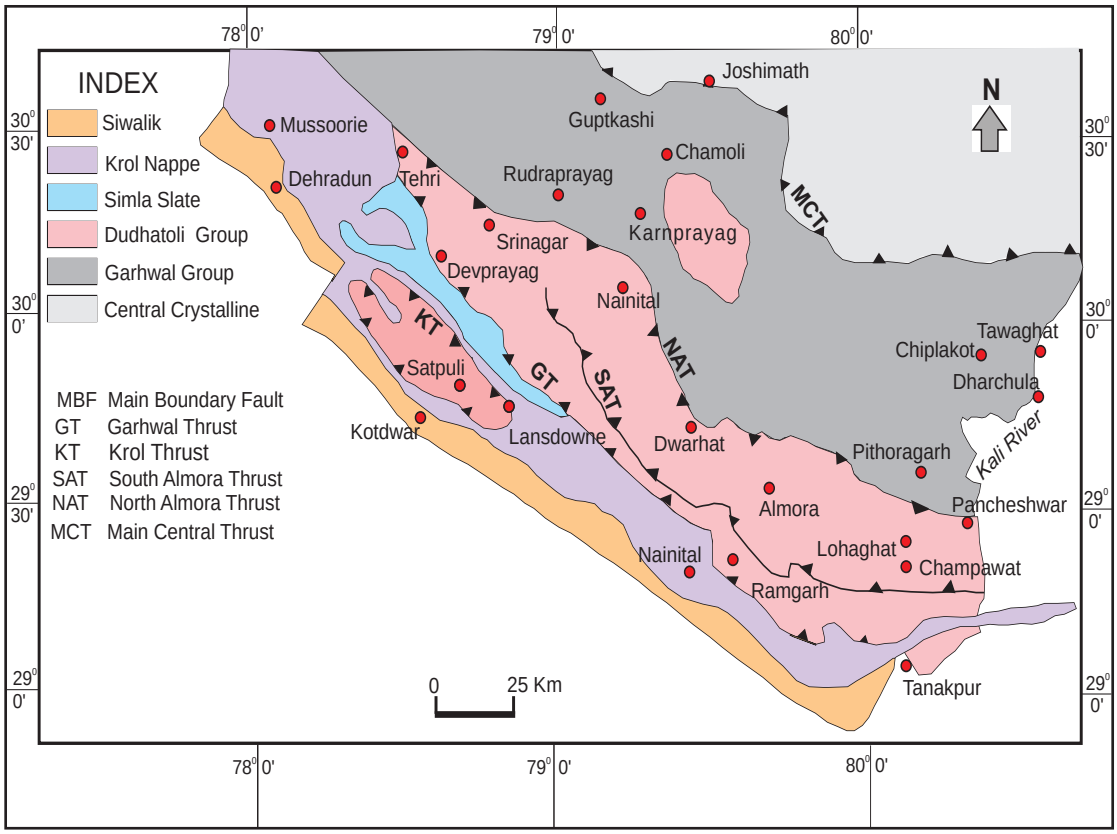

Figure 2.7: Geotectonic map of Kumaun and Garhwal Himalaya[33]

2.4.2 Human-Induced Causes

The natural instability and fragility of the landmass, coupled with ecological degradation, unwarranted changes of landscape under impact of various developmental and engineering projects, and faulty housing practices in the region makes it more vulnerable and prone to disasters. Given the circumstances of socio-economic vulnerability, slight disturbances in the sensitive zones, either due to human induced activities or other natural causes, can also lead to disasters. Unscientific development and land-use practices, poor socio-economic conditions, deforestation, increasing human and cattle pressure, increasing tourism pressure, etc. have also contributed to the factors governing vulnerability of people of the region to disasters.

2.4.2.1 Poor Socio-Economic Conditions

The disaster vulnerability of an area is determined by the factors of its social, physical, environmental and economic settings, which can make the land and its people susceptible to the impact of disasters. This may be related to the weaknesses in their capacity to understand, withstand and respond to hazards, and/or to bounce back after the disaster. Poor socio-economic conditions, either due to loss of environmental sustainability or degradation of natural resources, and inadequate avenues of alternative livelihood and prospects of local economic development, along with marginalization, non-access to goods and services, illiteracy and ignorance, govern people's preparedness and capacity to withstand a disaster. Poverty and deprivation, with lack of economic base to sustain and maintain safe housing and occupations extensively contribute to the vulnerability of the people. Lack of resources and capacity makes poor settle in hazardous and more vulnerable areas. However, changing livelihood choices, increased social aspirations and want of easy access to income has also increased unsafe construction of hotels and other tourism amenities in hazard prone locations along rivers.

Uttarakhand has been primarily an agricultural State where more than 75% of the population has been dependent on the agriculture sector including horticulture and animal husbandry for their livelihood. The economic condition of population in

general is not very good. It is a critical attribute increasing vulnerability of the people, which pushes them to move and settle in more vulnerable areas. Lack of road connectivity, irrigation facilities, food storage facilities, marketing/credit institutions in the rural hilly areas of the State also increases vulnerability of the people during disasters.

In the event of flood, landslide and earthquake, poor housing structures result in more damage and loss of lives. Design specifications of houses as well as material used for construction, particularly for making roofs and walls, have a direct bearing on the vulnerability of houses to common disasters like earthquake, landslides and floods. As per the Vulnerability Atlas of India, about 56% of the houses in the State are constructed using mud, un-burnt brick walls and stone walls; 37.9% using burnt brick walls; and 2.1% of concrete and wood walls. Majority of these houses consisting of mud, un-burnt/burnt brick walls and stone walls are more vulnerable and likely to get severely damaged or collapse during moderate intensity earthquake, landslide and flood[34].

2.4.2.2 Population Growth and Tourism Pressure

The increasing population along with yatra tourism in the hilly parts of Uttarakhand is one of the several reasons for increasing human vulnerability to natural disasters. As per census, the average population density per sq. km. in Uttarakhand in 2001 was 159, which increased to 189 in 2011. The population increased from 84.89 lakh in 2001 to 100.86 lakh in 2011.

In recent years, tourism has majorly contributed to the economy of the State. Tourism is one of the fastest growing industries and a major driver of economic growth and livelihood promotion in Uttarakhand. The economy of the State primarily depends on agriculture and tourism. The tourism sector contributes approximately 25% of Uttarakhand's GDP. About 1,00,000 people's livelihood depends on the tourism industry[35]. The State receives over 30 million tourists annually. The majority of tourists visit during the peak summer season (May-July) for pilgrimage and recreation[36]. The livelihoods of 83,320 households from the five worst recent flood affected districts (Bageshwar, Chamoli, Pithoragarh, Uttarkashi

and Rudraprayag) depend on tourism sector[37]. It is estimated that in the year 2013 about 60% of the pilgrims covered the entire route of the *char dhams;* 30% visited only two *dhams* and the remaining 10% visited only one of the two *dhams* of Gangotri and Badrinath.

The numbers of tourists going to Uttarakhand has grown by 300% in a decade during 2000 - 2010 from 1.11 crores to 3.11 crores[38]. However, the infrastructure to cater to this increase of tourists in the State has not increased proportionately. Due to the increase in the tourist inflow, several multi-storied hotels, and other amenities have been constructed even in the very eco-sensitive zones including some of the flood plain areas. In order to provide better services to the tourists and pilgrims, construction of roads, bridges, buildings and other infrastructures, several other developmental activities were also promoted. Impacts of these developmental activities on landscape and land-use, and people's socio-economic settings are to some extent responsible for increased ecological imbalances in the region. Taking up this sensitive issue into consideration, in February 2013, the Hon'ble High Court of Uttarakhand passed an order asking the State Government to demolish structures that had come up within 200 m of the river banks[39].

2.4.2.3 Development vs. Vulnerability

Vulnerability or susceptibility of a physical region or its society to natural hazards is basically the result of the prevailing conditions, which are often the consequences of the development pattern and practices. Therefore, the development practices play very important role in determining the vulnerability of a society or land to natural hazards. Development and disaster have a very close and multi-dimensional relationship. This relationship between disaster and development is very clearly visible in the Uttarakhand region. After the formation of the State, developmental activities have been speeded up considerably. Roads, buildings, hydro energy projects, tourist related infrastructure and, sand and stone collection from river channels are the main developmental activities, which influence the vulnerability of landscapes and local communities to natural hazards.

- **Road Construction**

In the hilly terrain, road construction is the main factor disturbing the ecological balance. It can damage the drainage pattern (both underground and surface), increase soil erosion, and lead to mass movement of the soil and rocks. The disturbance to the environment accelerates further if the road construction is carried out without taking the geological, geo-morphological, ecological aspects and drainage into consideration. Scientists have estimated the erosion from road sites to be ten times more than from agricultural fields, 200 times more than grass land and 2000 times more than forest cover. One kilometer of road constructed on hilly terrain requires removal of approximately 60,000 cubic m of debris from the site[40]. Unfortunately in Uttarakhand, most of the roads are constructed without giving much consideration to such important issues which result into increased instability and thus vulnerability to landslides.

- **Agricultural Practices**

Approximately, 14.0% of land area in Uttarakhand is under agricultural activities. This is the prime source of livelihood for more than 65% of State's total population[41]. Due to lack of alternative livelihood sources, despite constraints and hardships in practicing agriculture in the hilly terrain, people continue to engage in agricultural activities. Over time, people have started moving to more sensitive and unstable areas on steeper slopes for agricultural activities. Such agricultural practices have worsened the land instability and aggravated ecological and physical vulnerability to natural hazards. Agriculture on steeper slopes sometimes leads to serious problem of landslides and soil erosion[42].

Forest degradation and deforestation

Vegetation cover is very helpful in protecting land from soil erosion. According to the Forest Department, Government of Uttarakhand, a total of 38,814 ha of forest land has been transferred for various developmental schemes since creation of the state of Uttarakhand till 31 August 2014[43]. Apart from this, forest ecosystems in

Uttarakhand have suffered tremendous loss due to the forest fires. Besides causing direct economic loss of timber and other forest produce, forest fires also have a negative impact on forest regeneration, soil, ecology and climatic environment of the region. The natural and human-activity resulted change in the structure, location and extent of forest in higher altitude, hills and slopes, have complex functional implications on local weather events, land stability and also on inhabiting people's behaviour with their adjacent landscapes. The degradation and / or modification of forest cover and structure in the State has a negative impact on the soil cover and local climatic settings. Scientific investigations have proved that barren land is many times more susceptible to soil erosion as compared to land covered with forests. The degradation of forest has increased soil erosion, as is evident from frequent landslides, siltation in rivers and other drainage channels, deterioration of agriculture land, etc. in the State. The increased eroded sediments in the area are filling reservoirs and choking the streams. Springs in many parts of the State have dried up or have become seasonal. Floods in hilly regions have become a frequent phenomenon occurring even in case of small or medium level rainfall.

- **Dam and Reservoir Construction**

Dams or reservoirs are constructed on a river to impound or divert water for generation of electricity, flood control or irrigation (Figure 2.8). These are man-made structures creating an artificial check in the natural flow of river. Such artificial checks in river flow are known to disturb the normal flow pattern of the river disturbing the equilibrium in the ecosystem. Modification of land-use, and broadly saying the landscape, due to construction of dams may also increase vulnerability to hazards. In this regard, the Central Water Commission has stipulated Guidelines / Codal provisions for incorporating adequate measures to safeguard the environmental / ecological / geological / geo-technological concerns while evaluating the river valley projects, so that the vulnerability to disasters is minimized or avoided considerably.

Figure 2.8: Hydel power project in Srinagar, Uttarakhand[44].

In this context, the Ministry of Environment, Forests and climate change, Government of India had constituted an expert committee to study whether the construction of hydro-electric projects on Alaknanda and Bhagirathi rivers was a factor in aggravating the disaster of June 2013. Other than looking into the environmental impact of functioning as well as on-going hydro-projects, the committee was also supposed to examine the impact of the proposed 24 hydropower projects on the biodiversity of the region[45].

2.5 Causes of the Disaster-2013

The disaster 2013 can be attributed to widespread and exceptionally heavy rainfall across the State. The entire State was hit by 'heavy' (64.5-124.4 mm) to 'very heavy' (124.5-244.4 mm) rainfall, resulting into flash floods and landslides in numerous areas.

The districts of Bageshwar, Chamoli, Pithoragarh, Rudraprayag and Uttarkashi were the most affected. The worst impact of the disaster events of June 2013 on human settlements was in the Kedarnath shrine area (Gaurikund to Kedarnath), the

Mandakini valley, the Alaknanda valley (at Gobindghat and upstream), the Pindar valley, and along the banks of the river Kali in Dharchula area.

The causes for the disaster in the Kedarnath area, where it caused unprecedented devastation, have been a subject of several assessments. The main causes are discussed in the suceeding paragraphs:-

- **Geological Survey of India,** mentioning heavy rainfall and glacial melting as the main cause of the disaster, in its preliminary report stated "from 14 to 17 June 2013, Uttarakhand and adjoining areas experienced heavy rainfall, which was about 375 percent more than the benchmark rainfall during a normal monsoon. This caused the melting of Chorabari Glacier at the height of 3800 metres, and eruption of the Mandakini River which led to heavy floods near Gobindghat, Kedar Dome, Rudraprayag district, Uttarakhand and adjacent areas. It was also observed that very heavy and incessant rains during the period resulted in exceptionally high rise in the river discharges. The rise in the river level was of the order of 5 - 7m where the valley was wide and 10 - 12m where the valley was narrow. In the upper stretches of Mandakini, the stream gradient is high and valley profile is mostly narrow. The gush of water running down from Kedarnath and Rambara areas brought mammoth sediment load consisting of huge rock boulders (diameter ranging from 3 to 10 m). The heavy sediment load along with big boulders acted as tools of destruction and took away everything that came in their way. The enormous volume of water induced toe erosion along all the river valleys which in turn triggered landslides at a number of places" [46].

- **Wadia Institute of Himalayan Geology, Dehradun,** in the 25 July issue of Current Science (Dobhal, et al., 2013) described that the following two events caused devastation in the Kedarnath area of the Mandakini River basin"[47].

- **Event 1 -** "On 16 June 2013, at 5:15 p.m., the torrential rains flooded the Saraswati River and Dudh Ganga catchment area, resulting in excessive flow across all the channels. Following this, very active erosion began in all the other gulley areas causing excessive water and sediment accumulation in major rivers. As a result, large volumes of water struck the town, which simultaneously picked huge amount of loose sediment en route. The voluminous water studded with debris from the surrounding regions and glacial moraines moved towards Kedarnath town, washing off upper part of the city (Sankaracharya Samadhi, Jalnigam guesthouse, Bharat Seva Sangh Ashram, etc.) and leading to the biggest ever devastation we have seen in the region. The meteorological stations near Chorabari glacier recorded 325 mm rainfall at the base of the glaciers in two days on 15 and 16 June 2013. Due to heavy downpour, the town of Rambara was completely washed away in the evening of 16 June".

- **Event 2 -** "The second event occurred on 17 June 2013 at 6:45 a.m. It was caused by overflow and collapse of the moraine dammed Chorabari Lake which released large volume of water that caused another flash flood in the Kedarnath town leading to heavy devastation downstream (Gaurikund, Sonprayag, Phata, etc.). One of our study shows that the main cause of the Chorabari Lake collapse was torrential rains that the area received between 15 and 17 June 2013. Due to heavy rainfall the right lateral basin of the glacier, which is thickly covered by snow (>7 feet thick near the upper part of lake during fieldwork on 4 June 2013) rapidly melted because of rainwater allowing large amount of water accumulation in the Gandhi Sarovar lake. There were no outlets in the lake; the water used to simply release through narrow passages at the bottom of the lake. Suddenly millions of gallons of water accumulated in the moraine dammed lake within 3 days, which increased its potential energy and reduced shear strength of the dam. Ultimately the loose-moraine dam breached, releasing massive floodwaters causing enormous devastation in the Kedarnath valley area".

The Satellite view of Kedarnath area, showing drainage system, glaciers, lake and township is given in Figure 2.9.

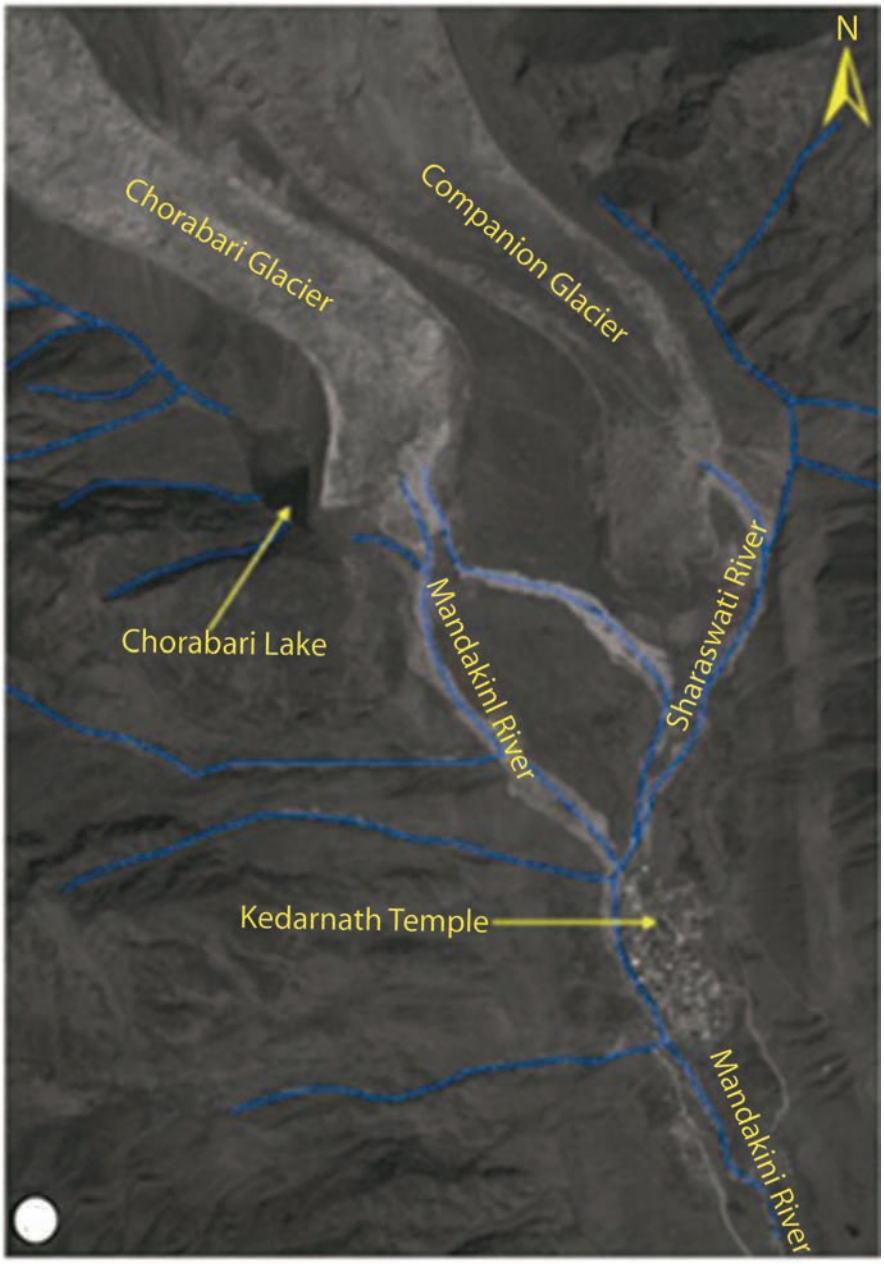

Figure 2.9: Satellite view of Kedarnath showing drainge system, glaciers, lake and township[48]

- **Uttarakhand State Disaster Management & Mitigation Centre** in its publication - the Asian Journal of Environment & Disaster Management (Routela, 2013, pp 43-51)[49] - mentioned that "There is no denying the fact that there were heavy rains in the area that led to increased discharge of the streams and rivers. The same is asserted by rainfall and water level data. Devastation in the Mandakini valley took place in two flood events on 16 and 17 June, 2013 and the latter was associated with the breach of Chorabari Tal that had accumulated enough water to force the moraine barrier to give way. The former event that washed off Rambara in the late evening of 16 June, 2013 could only happen by the blockade of the course of Mandakini in close proximity of Kedarnath so as to:

    - flood Kedarnath,
    - force water into the abandoned eastern channel of Mandakini and
    - ensure that enough water was impounded to devastate Rambara and Gaurikund with sudden removal of the barrier.

  Hydro-geomorphic setup of the area indicates that Dudh Ganga is the only major stream joining Mandakini between Kedarnath and Rambara that has the potential of bringing down enough debris to ensure impoundment of Mandakini river. Moreover, the confluence of Mandakini and Dudh Ganga is located at a place over which blockade could flood Kedarnath. Blockade at a downstream place would not affect Kedarnath because of high gradient of the river in the area. It was this blockade of Mandakini on 16 June 2013 that led to impoundment of the channel to the west of Kedarnath. The embankment on the left bank of the channel soon gave way and the abandoned channel of Mandakini to the east of Kedarnath became active. This event resulted in washing away of some people in the late evening of 16 June 2013 from Kedarnath that thus became water locked. Rising level of the landslide dammed lake forced the barrier to give way and the ensuing floods devastated Rambara and Gaurikund as also pedestrian bridge over Mandakini near Kedarnath. All connectivity with the area was thus snapped. Continuous rains

caused the level of water in Chorabari Tal to rise. With the recession of the glacier, the lake had a weak moraine barrier that could not withstand continuously rising hydrostatic pressure. Stage was thus set for a major disaster in Kedarnath and the barrier gave way at around 0700 hrs on 17 June 2013. The volume of water was enormous and it carried with it huge glacial boulders and outwash material that choked the western channel of Mandakini. As a result, flow of water and debris was diverted towards Kedarnath township that was thus ravaged. There was absolutely no warning and most people were taken by surprise and had no time to respond. Besides Kedarnath this event caused devastation in Rambara, Gaurikund, Sonprayag and other places."

- Dr. Dave Petley, Professor of Hazard and Risk in the **Department of Geography at Durham University, United Kingdom** interpreting publicly available satellite imagery, in his blogs[50] wrote: "The Indian National Remote Sensing Centre has released a new set of images of the Kedarnath area, collected using the RISAT-1 instrument. These are very high quality images that allow a proper analysis of the events that caused the disaster. These can be viewed in their excellent GIS system, Bhuvan. In a post two days ago I suggested that the disaster might have been caused by two different events, first a landslide induced debris that came from the area of the glacier to the northeast; second a glacial-related flow that came from the glacier to the northeast. In this post, I am going to take a look at each of these.... What is clear from this high resolution image is that the debris flow here was initiated by a landslide high on the hillside, which then ran down the slope entraining debris en route. At the slope toe it was channelized by the glacier into a narrow gully. It is clear that the flow eroded out a large amount of material in this area. Upon exiting the channel it spread out across the flood plain before striking the town. Rough parameters from Google Earth suggest a height difference from the crown of the landslide to the channel below of about 500 metres, and a length of about 1200 metres. The scar width is about 75 m, I think, so this is a large landslide. The area down slope of the failure was already a zone of active erosion, so the likelihood of entrainment was very high".

"The second event, which came from the glacial area to the northwest, was very different. This was the area of greatest uncertainty, but images tell us exactly what happened. This is the source area of the debris flow. In this area, fresh and muddy sediments can be seen. This suggests that the moraine had created a blocked basin in this area allowing water to build up in a pool. Eventually this pool overtopped the moraine barrier. Once overtopping of the barrier occurred, it catastrophically breached. This generated a very rapid release of the impounded water. The flow was so large that it overtopped the moraine on the other side of the glacial area, such that three flows were formed. One went southwest to join the valley from the earlier debris flow before swinging to the south to strike the town. This exploited an existing channel. The second was a much smaller flow that reoccupied a palaeo-channel. The volume of water and sediment that entered this channel was small, but it appears to have entrained debris en route (the channel widens down slope). Most of the debris flow travelled south down the main channel. The flow must have been huge as there is very substantial erosion in the area. This is the source of many of the boulders now seen in the town. The flow travelled southwards, eventually starting to spread and deposit sediments before striking the town. Thus, it is clear that Kedarnath was struck by an earlier flow from the northeast, then a later flow from the northwest. The latter was highly efficient, in part because of the earlier events and in part because the flow struck the town from two directions simultaneously".

- **Centre of Advanced Study in Geology, University of Lucknow** in Current Science (Singh, 2014) opined[51]: "On 16 and 17 June, 2013, heavy incessant rains overfilled the Gandhi Sarovar and induced landslides which blocked the Mandakini River system in the Kedarnath area and formed ephemeral lakes. Bursting of Gandhi Sarovar and the temporary lakes caused flash floods. Due to habitations within the Mandakini River valley and abandoned river channel, the left over part of the river was not capable of accommodating the high discharge. Therefore, it activated the abandoned channels, initiated new channels and increased the discharge of the main channel. This high energy flow of water laden with debris, increased the bank erosion, caused deepening of the valley and washed out almost everything that came in its way."

- **Uttarakhand Space Application Centre** in its report "Satellite based Observations of Devastation caused by Torrential Rainfall on 16 & 17 June 2013 in Kedarnath Dham and Mandakini Valley of Rudraprayag District" issued in June 2013 observed[52]: "antecedent rainfall saturated the area..which is one of the reasons for activation of landslide and flash flood in the region...Heavy rainfall and the snow cover in the area had raised the water level of the (Chaurabari) lake in the area which triggered the streams and lakes to overflow by saturating the moraines....cross section of the area shows very high gradient at the top of glacier to snout, steep to moderate slope in moraine deposit areas and moderate to gentle slope around Kedarnath and thereafter gradient increased from steep to very steep up to Gaurikund. Therefore, the velocity of debris flow was very high."

All the available inputs from various sources suggest that unprecedented heavy rainfall was the major cause for mammoth disaster in the State. The excessive rainfall (Figure 2.10, Table 2.6, Figure 2.11) probably caused by fusion of westerlies and monsoon clouds (Figure 2.12) led to heavy erosion and accumulation of water and sedimentation in the major river beds. A large accumulation of water in river and probably in glacial lake caused breach resulting into sudden escape of huge quantity of water, debris, moraines and boulders with excessive force washing off all that came in its way.

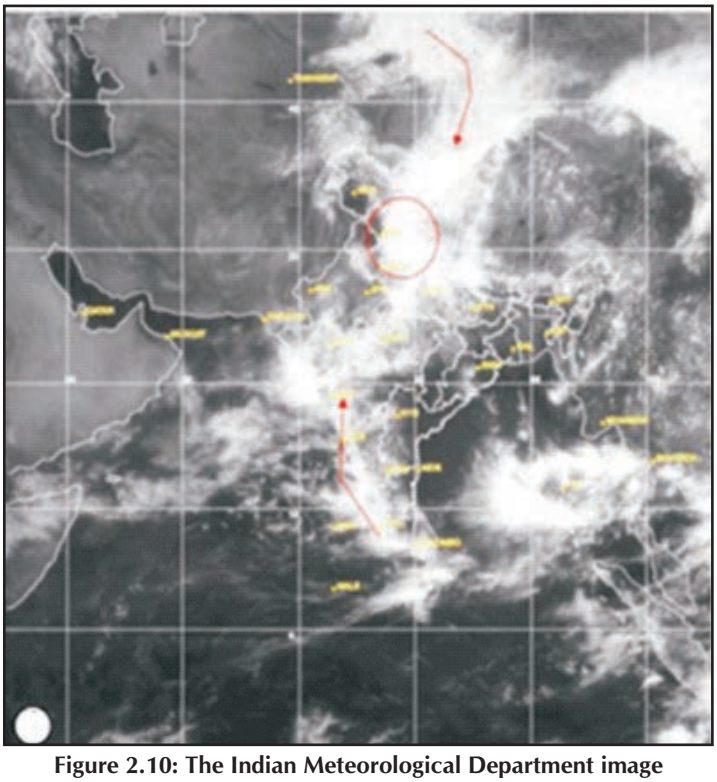

Figure 2.10: The Indian Meteorological Department image (17th June 2013) suggested the heavy rainfall on the higher Uttarakhand, Himachal and Nepal Himalaya[53]

Table 2.6: Precipitations at IMD stations locations in Uttarakhand from June 14 to 18, 2013[54]

	Rainfall (mm)				
Station Location	**14-Jun**	**15-Jun**	**16-Jun**	**17-Jun**	**18-Jun**
Almora	15.1	1	32.4	90	110
Bageshwar	15	3	61	160	63
Bhatwari	20	18	35	70	50
Bambasa	0	0	3	99	230
Barkot	10	15.4	112.6	20	20
Chamoli	1	40	58	80	100
Champawat	0	1	34	97	222
Dehradun	93.4	53.5	220	370	11.8
Deoprayag	0.5	7.3	130	163	70
Dunda	5	80	118	185	16
Haldwani	0	13	91	200	280
Haridwar	10	20	110	220	14
Jakholi	30	70	121	110	70
Joshimath	0	31.4	41.9	113.8	80
Karnaprayag	8.2	7	88	90	82.3
Kashipur	0	70	2	31	35
Keertinagar	0	0	78	96	65.2
Kosani	43.2	20.2	0	210	80
Kotdwara	0	9	73	23	52.2
Landsdown	20	0	64	51	28
Mukteshwar	14	0.4	78.5	240	183
Munsiyari	4	25	44	85	75
Mussoorie	20	44	137	150	8
Nainital	14.8	20	43.6	175.6	170
Pauri	15	0	44	51	38
Pantnagar	0	0	5.6	62.1	113
Pithoragarh	0	0	11.2	90	120
Purola	30	40	170	60	104
Ranikhet	4	0	16	38	120
Roorkee	0	5	51	150	15
Rudraprayag	4	11.8	89.4	92.2	59.2
Tehri	3.7	33.5	122	170	53.4
Tehri CWC	0.2	0	124	170	17.6
Tharali	0	15	58	173	80
Uttarkashi	15	50	130	162	19
Uttarkashi CWC	4.2	48.2	121.8	210	21.2

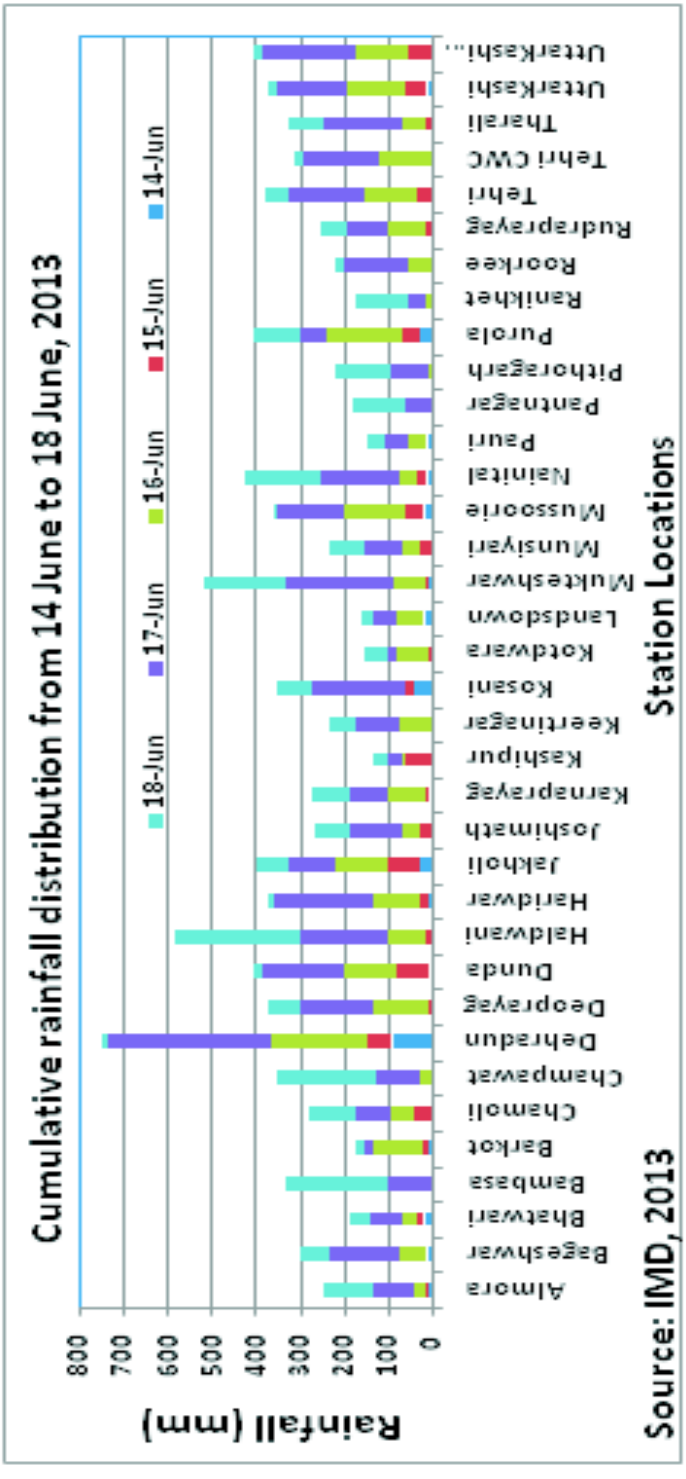

Figure 2.11 : Station-wise acumulated rainfall from 14 to 18 June 2013[55]

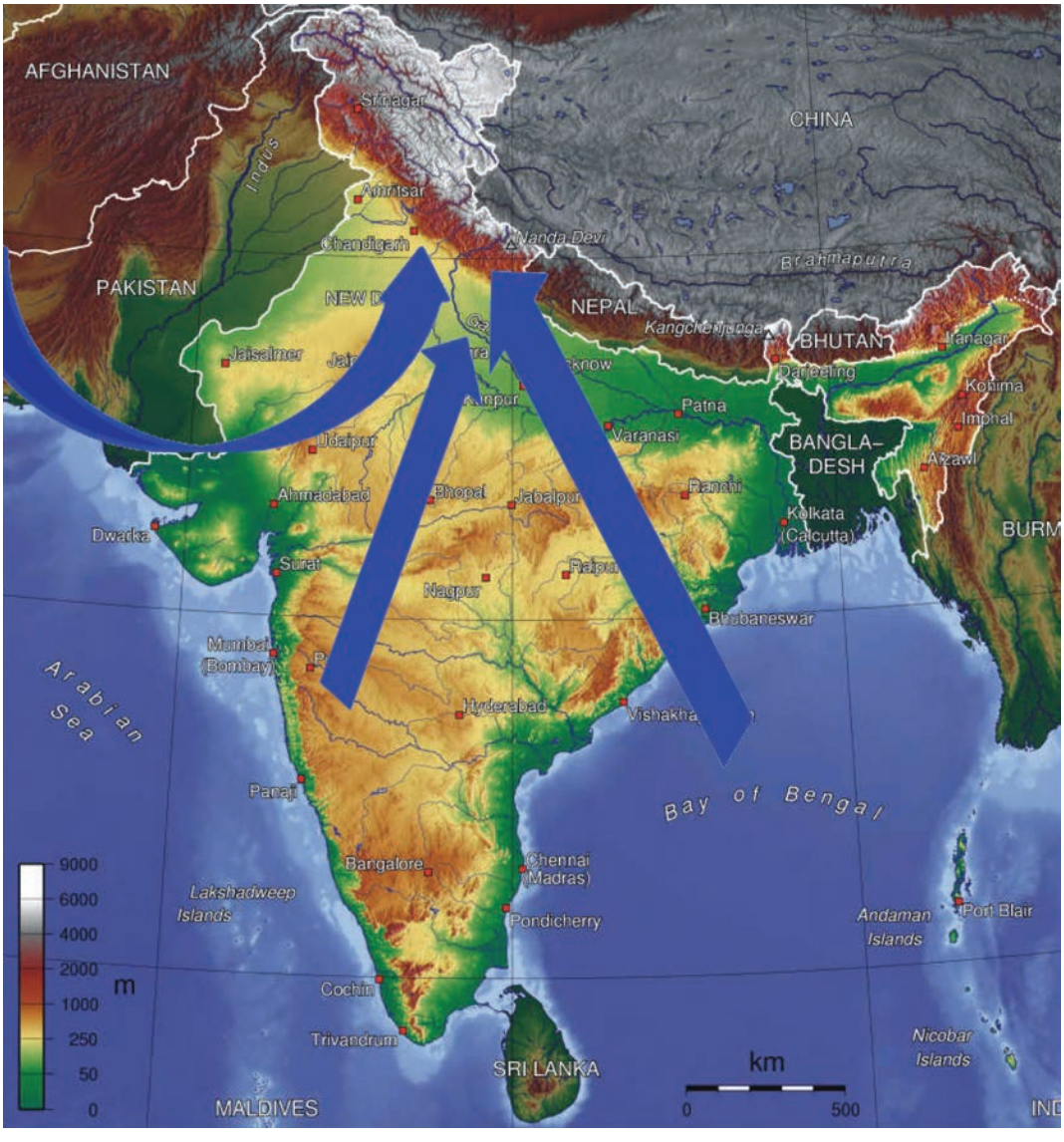

Figure 2.12: Map showing fusion of Westerlies and Monsoon clouds in June 2013

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