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NATIONAL LANDSLIDE RISK MANAGEMENT STRATEGY

September 2019

NATIONAL DISASTER MANAGEMENT AUTHORITY
MINISTRY OF HOME AFFAIRS
GOVERNMENT OF INDIA

National Landslide Risk Management Strategy

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A publication of:
National Disaster Management Authority
Ministry of Home Affairs
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These National Landslide Risk Management Strategy are formulated under the Chairmanship of Lt. Gen. N.C. Marwah (Retd.), Member, NDMA, in consultation with various stakeholders, regulators, service providers, and specialists in the subject field concerned from all across the country.

National Landslide Risk Management Strategy

National Disaster Management Authority
Ministry of Home Affairs
Government of India

राष्ट्रीय आपदा प्रबंधन प्राधिकरण
National Disaster Management Authority
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Preface

India, is vulnerable to different types of landslides which cause significant destruction in terms of loss of lives and property. As per GSI, about 0.42 million km^2 covering nearly 12.6% of land area of our country is prone to landslide hazards. Mountainous region of the North-Western Himalayas, the Sub-Himalayan terrain of the North-East, the Western and Eastern Ghats are prone to landslides covering 22 States and 2 Union Territories.

During the monsoon, these areas witness frequent landslides. Some of the major recent incidents are Kerala (2018), Himachal Pradesh (2018), Uttarakhand (2018), Tamenglong-Manipur (2018), Kalikhola, Manipur (June, 2017); Laptap, Pampare-Arunachal Pradesh (July, 2017); Malpa, Uttarakhand (August, 2017); Kotropi, Himachal Pradesh (August, 2017); Malin, Pune (July, 2014); Mirik, West Bengal (June, 2015) etc. causing huge loss to life and property. Most of the landslides occur due to heavy rainfall. Majority of landslide prone areas are located in the earthquake prone seismic Zone-IV and V. Thus these areas are also prone to earthquake-triggered landslides e.g. Sikkim Earthquake (2011), Kashmir Earthquake (2005), Chamoli Earthquake (1999), Uttarkashi Earthquake (1991) etc. In recent years, the incidences of landslides have increased due to extreme weather events, environmental degradation due to human interference and other anthropogenic activities resulting in heavy losses of human lives, livestock and property.

Thus, a need for formulation of **National Landslide Risk Management Strategy** was felt. NDMA constituted a Task Force for the formulation of national and local level strategy for landslide risk reduction. This strategy document is also fulfilling the fifth target of **Sendai Framework for Disaster Risk Reduction (2015-30)** i.e., Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020. Strategy document addresses all the components of landslide disaster risk reduction and management such as hazard mapping, monitoring and early warning system, awareness programmes, capacity building and training, regulations and policies, stabilization and mitigation of landslide etc. This strategy document envisages specific recommendations for the concerned nodal Agency, Ministries / Departments, States and other stakeholders, so as to avert or reduce the impact of future landslide calamities. For any further study and reference a detailed version i.e., the compendium may be referred.

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Acknowledgement

Formulation of National Landslide Risk Management Strategy covering various facets could be accomplished through constitution of a Task Force of Experts. The Task Force comprised of six Sub-Groups of experts addressing different components for landslide disaster risk reduction. Besides members of the Task Force, experts from various National and State Government Departments/Institutions provided useful inputs towards formulation of this document viz. Geological Survey of India (GSI), National Remote Sensing Centre (NRSC), National Institute of Disaster Management (NIDM), Defence Terrain Research Laboratory (DTRL)-DRDO, Remote Sensing Application Centre (RSAC)-UP, Border Roads Organisation (BRO), Wadia Institute of Himalayan Geology (WIHG), National Centre for Medium Range Weather Forecasting (NCMRWF), Central Building Research Institute (CBRI), Amrita University, Delhi University, Kumaun University, Jawaharlal Nehru University (JNU), Central Arid Zone Research Institute (CAZRI)-ICAR, Tehri Hydro Dam Corporation (THDC), United Nations Children's Fund (UNICEF), G.B. Pant National Institute of Himalayan Environment & Sustainable Development (GBPNIHESD), World Bank, Geohazards International (GHI), Save the Hills, National Centre for People's Actions in Disaster Preparedness (NCPDP).

NDMA acknowledges the dedication of experts of the Task Force who substantially contributed towards formulation of this document.

Efforts of Mitigation Division especially Dr. Ravinder Singh, Senior Consultant (Landslide & Avalanche) NDMA, Shri Nawal Parkash, Senior Research Officer, NDMA and Shri Akshay Rai Bansal, Junior Consultant are acknowledged.

It is hoped that this sincere effort will prove useful to the concerned States / Union Territories, Department and other stakeholders in formulating projects and plans that will lead to effective and holistic landslide risk reduction in the future.

Contents

Abbreviations

ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Centre
ADRC	Asian Disaster Reduction Centre
AVVU	Amrita Vishwa Vidyapeetham University
AWS	Automatic Weather Stations
BDMC	Block Disaster Management Committee
BIS	Bureau of Indian Standards
BRO	Border Road Organisation
BMTPC	Building Materials and Technology Promotion Council's
CADRI	Capacity for Disaster Reduction Initiative
CBDRMS	Community Based Disaster Risk Management Society
CBFDP	Community Based Family Disaster Preparedness and mitigation
CBO	Community Based Organisation
CBRI	Central Building Research Institute
CCA	Climate Change Adaptation
CLRSM	Centre for Landslide Research Studies & Management
CR	Central Region
CRRI	Central Road Research Institute
CSIO	Central Scientific Instruments Organization
CSIR	Council of Scientific and Industrial Research
CWC	Central Water Commission
DART	Dynamic Antecedent Rainfall Threshold
DDMA	District Disaster Management Authority
DDMC	District Disaster Management Committee
DEOG	District Emergency Operations Group
DGM	Department of Geology & Mining
DInSAR	Differential Interferometry Synthetic Aperture Radar
DMC	Disaster Management Cell
DMMC	Disaster Mitigation and Management Centre
DMSP	Disaster Management Support Programme
DoPT	Department of Personnel and Training
DPRI	Disaster Prevention Research Institute
DPR	Detailed Project Report
DRR	Disaster Risk Reduction
DST	Department of Science & Technology
DRDO	Defence Research Development Organisation

DRMP	Disaster Risk Management Programme
DTRL	Defence Terrain Research Laboratory
EFC	Expenditure Finance Committee
EO	Earth Observation
ER	Eastern Region
EU	European Union
FEMA	Federal Emergency Management Agency
FLHW	Front Line Health Workers
GFR	General Financial Rules
GIS	Geographical Information System
GNSS	Global Navigation Satellite System
GLOFs	Glacial Lake Outburst Floods
GoI	Government of India
GPR	Ground Penetrating Radar
GPS	Global Positioning System
GTA	Gorkha Territorial Administration
GSI	Geological Survey of India
IAHE	Indian Academy of Highway Engineers
IEC	Information Education and Communication
IIRS	Indian Institute of Remote Sensing
IIT	Indian Institute of Technology
IMD	Indian Meteorological Department
ISRO	Indian Space Research Organisation
ITC	ITC, University of Twente, The Netherlands
IUGS	International Union of Geological Sciences
LEWS	Landslide Early Warning System
LiDAR	Light Detection and Ranging
LHZ	Landslide Hazard Zonation
LHZMC	LHZ Monitoring Committee
LHM	Landslide Hazard Management
LSA	Landslide Susceptibility Analysis
LSER	Landslide Susceptibility Estimated Rate
LSI	Landslide Susceptibility Index
LSM	Landslide Susceptibility Management
LSV	Landslide Susceptibility Values
LSZ	Landslide Susceptibility Zonation
MAP	Mean Annual Precipitation
MEMS	Micro-Electro Mechanical Systems
MHA	Ministry of Home Affairs

MHRD	Ministry of Human Resource Development
MNREGA	Mahatma Gandhi National Rural Employment Guarantee
MoEFCC	Ministry of Environment Forest and Climate Change
MoES	Ministry of Earth Sciences
MoM	Ministry of Mines
MoR	Ministry of Railways
NBC	National Building Code
NCC	National Cadet Corps
NCS	National Centre of Seismology
NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NER	North Eastern Region
NGO	Non-Governmental Organisation
NIDM	National Institute of Disaster Management
NIT	National Institute of Technology
NHAI	National Highway Authority of India
NLMP	National Landslide Mitigation Policy
NLMS	National Landslide Mitigation Strategy
NLSM	National Landslide Susceptibility Mapping
NPCBAERM	National Programme for Capacity Building of Architects in Earthquake Risk Management
NPCBEERM	National Programme for Capacity Building of Engineers in Earthquake Risk Management
NSS	National Service Scheme
NRDMS	Natural Resource Data Management System
NRSC	National Remote Sensing Centre
PRI	Panchayati Raj Institution
PS InSAR	Persistent Scatterer Interferometry Synthetic Aperture Radar
PWD	Public Works Department
RES	Rural Engineering Services
RIRD	Regional Institutes of Rural Development
RS	Remote Sensing
RSAC	Remote Sensing Applications Centre
RT	Rainfall Threshold
SASE	Snow and Avalanches Studies Establishment
SAR	Synthetic Aperture Radar
SDMA	State Disaster Management Authority
SDRF	State Disaster Response Force
SFC	Standing Finance Committee

SFM	Slope forming material
SIL	Seismicity Induced Landslides
SIRD	State Institutes of Rural Development
SoI	Survey of India
SOP	Standing Operating Procedures
SMS	Short Message Service
TAC	Technical Advisory Committee
TCPO	Town and Country Planning Organization
TDMC	Tehsil Disaster Management Committee
TEC	Technical Evaluation Committee
TNA	Training Need Assessment
UAV	Unmanned Aerial Vehicle
UDPFI	Urban Development Plan Formulation and Implementation
UGC	University Grants Commission
ULBs	Urban Local Bodies
UNDP	United Nations Development Programme
UNESCO	United Nations Education Scientific and Cultural Organisation
UNISDR	United Nations International Strategy for Disaster Reduction
USGS	United States Geological Survey
VDIT	Village Disaster Intervention Teams
VDMC	Village Disaster Management Committee
VDMT	Village Disaster Management Teams
WB	World Bank
WIHG	Wadia Institute of Himalayan Geology
WHO	World Health Organisation
WSN	Wireless Sensor Network

Executive Summary

Landslide hazards rank high among the hydro-geological hazards because they pose a threat to life and livelihood ranging from disruptions of normal activities to widespread loss of life, property and destruction in large parts of mountainous region of India. Himalayan and other hilly regions of India are affected by landslides and landmass movement activities. Some of the major landslide incidents that occurred in the past are Katropi-2017 (Himachal Pradesh), Laptap Pampare-2017 (Arunachal Pradesh), Mirik-2015 (West Bengal), Malin-2014 (Pune), Dasalgaon-2007 (Maharashtra), Varunavat Parvat-2003 (Uttarakhand), Amboori-2001 (Kerala), Malpa landslide-1998 (Uttarakhand), Kalimpong-1993 (West Bengal), Kohima-1993 (Nagaland) etc.

As per the Disaster Management Act, 2005 the National Disaster Management Authority (NDMA), a statutory and apex body under the Chairmanship of the Prime Minister, is mandated to lay down the policies, plans and guidelines for disaster management to ensure timely and effective response to disasters. In June 2009, NDMA released the National Disaster Management Guideline on Management of Landslides and Snow Avalanches formulated in consultation with the Nodal Ministry/Agency (MoM/GSI) and other core group members from concerned Central, State departments and academia, laying down national policy for the management of landslide related hazards in the country.

During the 11th Formation Day of NDMA at Vigyan Bhawan a Technical Session on "Landslide" was held on 28th Sept., 2015 in which a presentation on National Landslide Risk Management Strategy was made by NDMA. It was decided that NDMA will constitute a Task Force of experts for formulation of National Landslide Risk Management Strategy. The concept was widely discussed in NDMA and a Task Force comprising of six Sub-Groups was constituted to formulate important documents related to the strategy on 17th June 2016.

The Task Force was divided into six Sub-Groups as under:-

a) **Sub-Group I:** Generation of User-Friendly Landslide Hazard Maps

b) **Sub-Group II:** Development of Landslide Monitoring and Early Warning System

c) **Sub-Group III:** Awareness Programmes

d) **Sub-Group IV:** Capacity Building and Training of Stakeholders

e) **Sub-Group V:** Preparation of Mountain Zone Regulations & Policies

f) **Sub-Group VI:** Stabilization and Mitigation of Landslides and Creation of Special Purpose Vehicle (SPV) for Landslide Management

The formulation of overall National Landslide Risk Management Strategy was planned to be developed through six independent working groups under six Heads of Sub-Groups assisted by experts in relevant fields.

Highlights of Strategy:-

The strategy document clearly brings out the message for the need to strengthen and mainstream landslide disaster preparedness, mitigation, response and relief mechanism through mapping, early warning system (EWS), awareness generation, capacity building, formulation of mountain zone regulations / policies and mitigation of problematic landslides. It can be summarized as follow:

- **Landslide Hazard Zonation** - It covers aspects of reliability and validation of landslide zoning maps in Indian scenario and proposes future plan of activities for landslide zoning. It recommends Landslide Hazard Zonation maps to be prepared at the following scales:

  (i) at macro scale (1:50,000 / 25,000) ,

  (ii) at meso level (1:10,000)

  It focuses on making use of advanced state-of-the-art tools such as Unmanned Aerial Vehicle (UAV), Terrestrial Laser Scanner, and very high resolution Earth Observation (EO) data .A suitable monitoring mechanism and quality checking option may be established at all levels to ensure quality of deliverables.

- **Landslide Monitoring and Early Warning System** - The strategy document highlights the past work,

best practices and present status in the field of Landslide Early Warning System (LEWS), rainfall threshold based modelling, ground based wireless instrumentation and real time monitoring system for landslide prediction, earthquake triggered landslide, monitoring mechanism of landslides and gap areas in landslide monitoring and development of early warning system.

For future prospects, technical recommendation for developing and implementing rainfall thresholds, Numerical Weather Prediction (NWP), Automatic Rain Gauges, Wireless Sensor Network (WSN), Micro-Electro Mechanical Sensors (MEMS) etc have been included.

- **Awareness Programmes** - The strategy spells out need of awareness programmes, review of past work and best practices, identification of gaps, as well as recommendations and implementation strategies. It aims towards a culture of awareness generation and preparedness; so that people in the society become alert and aware in case of an emergency or take some preventive measures before the disaster strikes. A participatory approach has been defined so that each section of the community is involved in the awareness drive. Since the community is the first to confront the disaster before any aid reaches them, a mechanism of awareness is framed to involve and educate the community.
- **Capacity Building and Training of Stakeholders** – Strategy document highlights the past work, gaps, implementation strategy, financial implications and monitoring mechanism for capacity building and training in landslides. The key recommendations include a Nationwide Training Need Assessment (TNA) in Landslide Risk

  Management and Inclusion of new technology inputs for capacity building and training programs on landslide DRR. It also focuses on identifying targets group for training on landslide DRR and most importantly, strengthening the response framework through capacity building and training of vulnerable communities at grass root level.
- **Preparation of Mountain Zone Regulations and Policies** - The strategy describes the formulation of land-use policies and techno legal regime, updation and enforcement of building regulations, review and revision of BIS code / guidelines for landslide management, proposed amendment in town and country planning legislations, regulations for land use zoning for natural hazard prone areas as well as additional provisions in development control regulations for safety in natural hazard prone areas, additional provisions in building regulations / bye-laws for structural safety in landslide hazard prone areas.
- **Stabilization and Mitigation of Landslide and Creation of Special Purpose Vehicle (SPV) for Landslide Management** - The strategy describes the formulation of land-use policies and techno legal regime, updation and enforcement of building regulations, review and revision of BIS code / guidelines for landslide management, proposed amendment in town and country planning legislations, regulations for land use zoning for natural hazard prone areas, additional provisions in development control regulations for safety in natural hazard prone areas, additional provisions in building regulations / bye-laws for structural safety in landslide hazard prone areas.

Except, strategy document other main outcomes and efforts of Task Force are listed as under:-

a) Pilot project on “Generation of Large Scale User Friendly Landslide Hazard Zonation (LHZ) maps and landslide inventory of Route corridor Uttarakhand”.

b) Pilot project on “Development and Evaluation of Low-Cost Landslide Monitoring Solutions”.

c) Training and capacity building of States/UT’s and other stakeholders in landslide mitigation and preparation of standard Detailed Project Report (DPR).

d) Proposal on Creation of “Centre for Landslide Research Studies and Management (CLRSM)” as per recommendation made in the NDMA’s Guideline on Management of Landslide and Snow Avalanches (2009).

This is a small but significant step towards mainstreaming and strengthening of landslide disaster risk reduction (DRR) in disaster management activities to reduce risk and minimize losses. This strategy document could provide guidance to the concerned States / UTs, Ministries / Departments and other stakeholders during conceptualization/finalization of their developmental projects. It will also serve as a guide book for the SDMAs / DDMAs in formulating their disaster risk management initiatives.

1 Generation of User-Friendly Landslide Hazard Maps

1.1 Introduction

Landslides account for considerable loss of life and damage to communication routes, human settlements, agricultural fields and forest lands in India. Based on the general experience with landslides, a rough estimate of monetary loss is of the order of Rs. 100 crore to Rs. 150 crore per annum at the 2011 prices for the country as a whole (Disaster Management in India, MHA, Govt. of India, 2011). In India, excluding the permafrost regions in the north, about 0.42 Million km2 areas of the landmass (12.6%) is landslide-prone which are spread over 19 odd numbers of States/Union Territories and are spreading over more than 65,000 villages in hilly/ mountainous areas (Fig. 1).

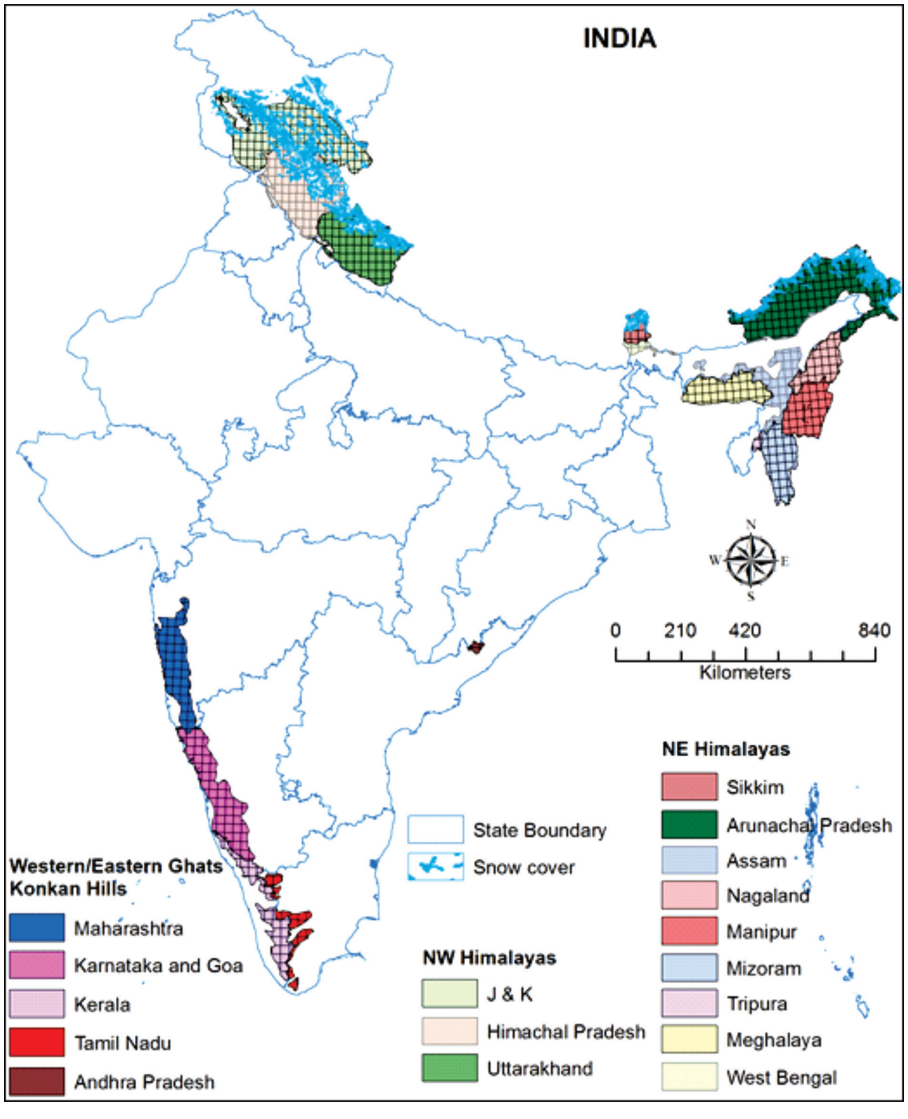

Figure 1: Major landslide prone areas of India (0.42 Million km²)

Major parts of the northern states of India namely Jammu & Kashmir, Himachal Pradesh, Uttarakhand and north-eastern states of the country viz. Sikkim, Arunachal Pradesh, Mizoram, Nagaland, Manipur, Meghalaya, Assam and Tripura are vulnerable to landslides due to fragile geology, active tectonics, high relief, critical slopes, intense rainfall as well as anthropogenic activities at various locations of these states. Western parts of Maharashtra, Karnataka, Goa and Kerala covering parts of Western Ghats and eastern parts of Andhra Pradesh and Tamil Nadu in Eastern Ghats are also vulnerable to landslides. Hence, there is an urgent need for holistic approach to landslide mitigation and management on the basis of region and area specific landslide hazard information with structural and non structural mitigation as the core theme.

Landslide Zoning is the division of hill or mountainous areas into homogeneous spatial areas/ slope according to their degrees of actual or potential landslide susceptibility, hazard or risk.

Landslide Susceptibility Zoning uses an inventory of past landslide incidences together with an assessment or prediction of the spatial areas/ slope with a likelihood of landslides in the future. Susceptibility zoning thus involves the spatial distribution and rating of the terrain units according to their propensity to produce landslides. This is dependent on the topography, geology, geotechnical properties, climate, vegetation and anthropogenic factors such as development and clearing of vegetation.

Landslide Hazard Zoning uses the landslide susceptibility maps and assigns an estimated frequency (i.e. annual probability) to the potential landslides of certain magnitude. It should consider all landsliding events which can affect the study area including landslides which are above the study area but may travel onto it, and the landslides below the study area which may retro grade up-slope into it.

Landslide Risk Zoning depends on the elements at risk, their temporal–spatial probability (or exposure) and vulnerability and is the ultimate aim of any zoning exercise. Administrator/ Planners/ Insurers are mostly interested in risk maps for their accurate planning and allocation of resources etc. For new areas under planned developments, an assessment will have to be made of these factors. For areas with existing development, it should be recognized that risks may change with additional development and thus, risk maps should be updated on a regular basis.

The ultimate aim of all the above zoning activities is to comprehensively manage the landslide risk in fragile hilly and mountainous areas so that losses due to landslide hazards are substantially reduced. Therefore, landslide zoning is always to be construed and viewed as an integral part of the broader landslide risk management framework (Figure 2), proposed by Fell at al. (2005), which has widely been accepted internationally. In India, we must make sincere and all-out attempts to convert our susceptibility maps into true hazard and risk maps following the above-mentioned internationally-accepted methodologies.

However, landslide zoning is being carried out for specific purposes and for regional, local and site-specific planning as well as safe and optimal use of landmass. The outputs are usually in the form of one or more of the following: landslide inventory map; landslide susceptibility map; landslide hazard and risk maps; and associated reports.

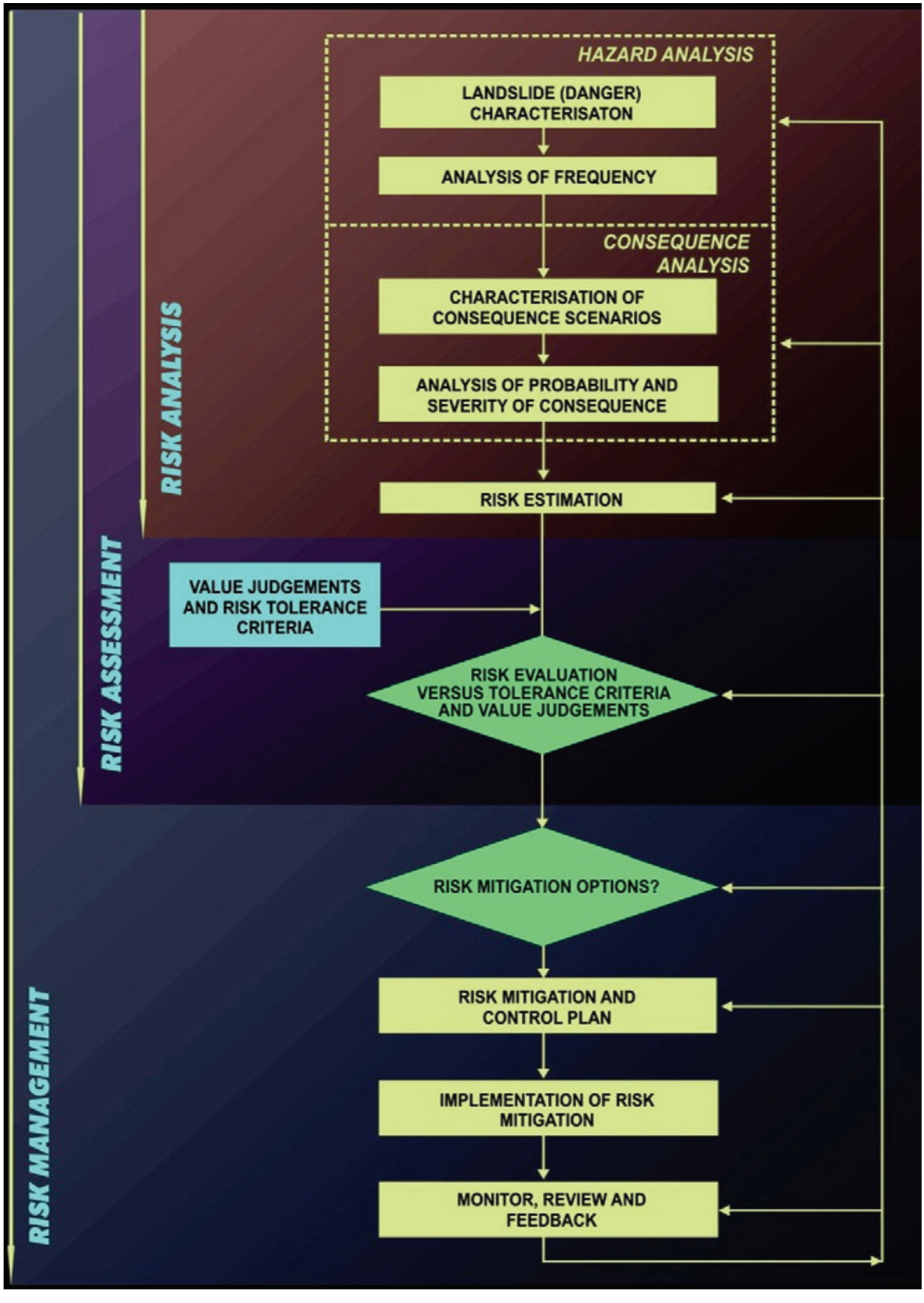

Figure. 2: Landslide Risk Management Framework (Fell et al., 2005)

Table 2: Landslide Zoning Scales and their Applications

Description	Scale	Typical area of study	Examples of zoning application
Small (National to Regional Zoning)	<1:100,000	>10,000 km^2	• **Landslide inventory and susceptibility zoning** to inform policy makers and the general public
Medium (Provincial to Regional Zoning)	1:100,000 to 1:25,000	1000-10,000 km^2	• **Landslide inventory and susceptibility zoning** for regional development; or very large scale engineering projects. • Preliminary level hazard mapping for local areas
Large (Local Zoning)	1:25,000 to 1:5,000	10-1000 km^2	• **Landslide inventory, susceptibility and hazard zoning for local areas**. • **Intermediate to advanced level landslide hazard zoning** for regional development. • **Preliminary to intermediate level risk zoning** for local areas and the advanced stages of planning for large engineering structures, roads and railways
Detailed (Site specific zoning)	>5,000	1-10 km^2	• **Intermediate and advanced level hazard and risk zoning** for **local and site-specific areas** and for the design phase of large engineering structures, roads and railways

1.2 Identified Gaps

1. Landslide zoning maps so far available in India are mostly LSZ maps; however, in most of the cases, they are termed as LHZ maps despite not having any connotation about magnitude and temporal predictions.
2. The LSZ maps prepared till 2014 in India are concerned only to important route corridors and at some discrete locations (which have witnessed damage due to landslides) in some highly landslide prone States.
3. Single Seamless state-wise/ district-wise landslide zonation maps are mostly not available for landslide prone northern, northeastern states and for Eastern and Western Ghats regions, which, however this has recently been taken care of on regional/ medium scale (1:50,000) by GSI's National Landslide Susceptibility Mapping (NLSM) programme since 2014-15.
4. In India, LSZ maps for the same area have also been created by different workers of different organizations following different methodologies. In such cases, which of the LSZ map is to be follow for mitigation measures is not clear to the users.
5. Majority of the existing LSZ Maps are lacking details of the devastating landslide events of the past. Therefore, landslide incidence map prepared from multi-temporal and event-based sources along with its detailed geo-parametric attributes needs to be measured while ranking and weighting the thematic geo-factors for preparation of LSZ maps.
6. Most of the available LSZ maps are on 1:50,000 scale because of its easy availability of source datasets and methods. But for effective developmental planning, its utility has some limitations. Moreover, on scale 1:50,000, active landslide zones of smaller dimensions having sizes of 50 m×50 m appear as a dot (1 mm×1 mm) on 1:50,000 scale map.
7. Slope cutting and blasting activity for construction and widening of hill roads are

triggering many landslides, which are in many cases merely 10-30m wide. Such small landslides are often life-threatening on hill roads and are difficult to depict on 1:50,000 scale LSZ maps.

8. From meso/large scale (1:10,000) analysis, reliance on more number of field-based inputs and analytically-determined attributes of slope forming material are needed, which are not only time consuming but also costly in nature and cannot be implemented for large areas. Therefore, areas/sectors undertaken for 1:10,000 (meso) scale LSZ must be prioritized based on proper justification and evaluation of its risk scenarios.
9. Scope of finding linkages of structural mitigation measures with meso/ local scale LSZ, though difficult may be sought, so that more direct use of LSZ maps can be justified, for which some research projects can also be launched by Department of Science & Technology (DST).
10. Most of the existing LSZ and landslide susceptibility maps are lacking administrative boundaries such as district, Tehsil, block and village boundaries superposed on hazard zones.
11. Drainage divides are rarely shown on LSZ maps and only little drainage are shown. Hence, lack of drainage divides in general and watershed boundaries in particular make it almost impossible to integrate landslide mitigation measures with ongoing watershed development projects.
12. Names of the elements at risk (viz. roads, canals, railway line tunnels, bridges) falling within the high, very high and severe hazard zones are missing in the existing LSZ maps.
13. Existing stability measures are neither shown not mentioned in the presently available LSZ maps because of scale constraints.
14. No detailed landslide inventory created on the basis of 1:10,000 scale macro level LSZ maps is available for formulation of landslide mitigations planning at district, Tehsil, block and village level. Therefore, landslide inventory mapping needs to be carried out at the highest possible level of larger scales (preferably 1:10,000 or larger), so that none of the smaller landslides are missed.
15. Landslide Susceptibility Management (LSM) maps are not available for all areas for which LSZ maps are available. Even the available Landslide Susceptibility Management (LSM) maps are lacking site specific structural and non-structural mitigation measures, since most of such LSZ maps are on 1:50,000 scale.
16. The mitigation measures recommended in the existing LSM maps are generalized ones, such as “afforestation” and “biotechnical measures” without any mention of the particular varieties of the fast-growing trees and useful grasses to be grown or list of biotechnical measures to be taken for stabilizing the hill slope.
17. The available LSM maps address the anthropogenic intervention (in landslide susceptible zones) very casually by suggesting measures such as “avoid further construction” etc. This makes it difficult for the authorities to ensure strict adherence to land use regulations such as complete ban on construction activity in a landslide hazard prone area.
18. Existing LHM maps do not address the crucial aspects of overloading and or under cutting of hill slope due to anthropogenic activities and therefore, provide no clear guidelines for removal of those manmade constructions in particular which are overloading or undercutting the hill slope or blocking, diverting or narrowing the natural drainage courses.

1.3 Future Strategies

A strategy has to be developed by NDMA and MHA in consultation with Survey of India to make available 1:10,000 scale Topographic base maps or contour maps for identified areas/ sectors in India, where 1:10,000 scale landslide susceptibility zonation is required (Table 2).

The following 47 sectors for 1:10,000 scale landslide susceptibility zonation in Table 2 were

identified after evaluating the recently-generated base level landslide susceptibility information of NLSM projects of GSI (1:50,000). However, this list is not exhaustive; the same will be augmented further as soon as the new data and information of NLSM are being generated through the on-going NLSM project of GSI in different regions in the coming years.

Table 2: List of some identified/ prioritised sectors/ areas where 1:10,000 scale landslide susceptibility zonation can be taken up on availability of suitable quality 1:10,000 scale Topographic Base Maps suitably supplied by Survey of India or NRSC.

State	Sectors/ Areas
Uttarakhand	Guptkashi-Gaurikund Sector (Keadrnath route)
	Pipalkoti – Helang – Animath Sector (Badrinath route)
	Alaknanda bridge (Joshimath)-Vishnugad -Binakuli Sector (Badrinath route)
	Rishikesh-Rudraprayag Sector (Haridwar-Badrinath route)
	Netala -Batwadi - Sukki top Sector (Gangotri Sector)
	Narendra Nagar-Uttarkashi Sector (Rishikesh-Gangotri Route)
	Chamba-Dunda -Matli Sector (Rishikesh-Gangotri Route)
	Naugaon - Barkot -Hanuman Chatti Sector (Yamnotri Route)
	Mussoorie Township
	Nainital Township
Himachal Pradesh	Pandoh-Thalot stretch along NH-20, Mandi district
	Dharampur to Joginder Nagar SH-19 road stretch, Mandi district,
	Manali-Marhi-Rohatang-Koksar-Sissu road section, Kullu and Lahaul & Spiti districts
	Kangu-Jarol- Harabagh-Bari along NH-20, Mandi
	Chaura-Bhabhanagar NH-22 section, Kinnaur district, H.P., (FS2016-17)
J&K	NH-1A between Udhampur and Patni Top sector
Assam	Maibang – Jatinga Road Section
Mizoram	Aizawl Township
	Road Sector between Aizawl airport and Aizawl Township
Manipur	Imphal-Ukurul road section
Nagaland	Dimapur-Kohima road section
	Dimapur-Mao gate road section
	Kohima Township
Sikkim	Road corridor along North Sikkim Highway (NSH) between Mangan and Lachung/ Lachen
	Gangtok town and its surrounding (6 km2)
	Road sector between Singtam, Dikchu and Rangrang
	Road sector between Ranipool and Pakyong
	NH-10 between Rongpoh, Singtam, Ranipool and Gangtok
West Bengal	NH-10 between Sevoke and Rongpoh
	Road Sector between Gorubathan and Kalimpong
	Lava and Lolegaon Townships
Tamil Nadu	Ooty and Coonoor Townships

Kerala	Neriyamangalam - Munnar stretch of Kochi –Dhanushkodi road (NH-49)
	Vazhikkadavu - Nadugani stretch of Calicut - Gudallur road (SH -28)
	Moolamattom - Painavu stretch of SH – 44
	Munnar Town
Maharashtra	The Malshej Ghat (~15 km.) long Ghat road stretch on Vizag - Ahmadnagar - Mumbai Highway - NH-222
	The Kalghar Ghat (~11 km.) long stretch of Mahabaleshwar - Medha - Satara SH-73.
	Karul Ghat section (~10 km length) from Kolhapur to Padel (via GaganBawda - Vaibhavwadi – Talere) of SH-115.
	Tamhini Ghat hill route section of Pune - Mangan Road, and is in fact, a hilly pass which cuts across the Western Ghat Escarpment to join Pune to Konkan region.
	Varandh Ghat (~18 km) forms part of SH-70 connecting Pandharpur, a pilgrim place in Solapur district to Bankot, a port town in Ratnagiri district.
	Location/ Area: SoI Toposheet No.: 47F/08; District: Raigad (Parts of Mahad Tal.); Coordinates: Bounded between: Lat.: $18^0$00'N to $18^0$15'N; Long: $73^0$15'E to $73^0$30'E.
	Location/ Area: SoI Toposheet No.: 47E/12; District: Pune (Parts of Ambegaon Tal.); Coordinates: Bounded between: Lat.: $19^0$00'N to $19^0$15'N; Long: $73^0$30'E to $73^0$45'E.
	Location/ Area: Mahabaleshwar hill town (SoI Toposheet No.: 47G/09); District: Satara District (Mahabaleshwar Tal.); Coordinates: Lat.: $17^0$55'50.62''N, Long.: $73^0$38'51.84''E
	Location/ Area: Panchgani Laterite Plateau (SoI Toposheet No.: 47G/13); District: Satara District (Mahabaleshwar Tal.); Coordinates: Bounded between: Lat.: $17^0$55'N to $17^0$57'N; Long: $73^0$47'E to $73^0$50'20''E.
	Location/ Area: Matheran hill town (SoI Toposheet No.: 47F/05 and 47E/08); District: Raigad District (Karjat Tal.); Coordinates: Bounded between Lat.: $18^0$57'N to $19^0$03'N, Long.: $73^0$15'E to $73^0$20'E
	Location/ Area: Marleshwar Temple Complex (SoI Toposheet No.: 47G/12); District: Ratnagiri District (Sangameshwar Tal.); Coordinates: Bounded between Lat.: $17^0$00'N to $17^0$05'N , Long.: $73^0$40'E to $73^0$45'E

In this process, the methodology of landslide susceptibility zonation on 1:10,000 will get strengthen up in near future. These 1:10,000 LSZ maps will subsequently be converted into landslide hazard and risk maps for effective utilization in land use zoning regulation.

1.4 Implementation Strategy

1.4.1 Short Term Implementation Strategy

- Formation of LHZ Monitoring Committee (LHZMC) under NDMA in consultation with nodal agency (GSI) and other agencies competent in carrying out LHZ mapping work.

  [**Action**: NDMA in consultation with GSI and other stakeholders]

- Collection and cataloguing of all the available Landslide Hazard Zonation (LHZ) and Susceptibility Zonation (LSZ) maps, reports and atlases created by various state and central government departments, institutions and agencies etc. by the nodal agency (GSI).

  [**Action**: Ministry of Mines (MoM)/Geological Survey of India (GSI) in consultation with Technical Advisory Committee (TAC) and LHZMC]

- Taking up pilot projects at least at 10 sites in next two years to strengthen up of existing methodology right up to hazard and risk level.

  [**Action**: Ministry of Mines (MoM)/GSI, States

and academic institutions in consultation with TAC and LHZMC]

- Hiring group of expert agencies for taking up the meso level LHZ map creation work in different landslide prone regions of the country.

  [**Action**: Ministry of Mines (MoM)/GSI in consultation with TAC and LHZMC]

1.4.2 Long Term Implementation Strategy

- Creation of meso level LHZ Maps on 1:10,000 scale in order to cater to the requirements of Landslide Hazard Management planning at District, Tehsil and Block level.

  [**Action**: Ministry of Mines (MoM)/GSI in collaboration with State Governments and other academic institutions]

- Meso level LHZ Maps on 1:10,000 Scale of the already prioritised sectors (47 sectors) should be created using very high resolution remote sensing data, detailed field input, GPS, LiDAR and GIS techniques within four years.

  [**Action**: Ministry of Mines (MoM)/GSI in collaboration with states and academic institutions in consultation with TAC and LHZMC]

- Use of web-based and app-based dissemination tools for preparation of maps for common use not only by the administrators but also by the community, tourists etc.

  [**Action**: Ministry of Mines (MoM)/GSI in consultation with TAC and LHZMC]

1.5 Financial Implications

1.5.1 Central Government Sources

i) Ministry of Mines (MoM)

Ministry of Mines (MoM) can propose separate budget head/sub head for creation of meso level LSZ maps on 1:10,000 scale and micro level LSZ maps on 1:4,000, if there is no such provision as yet.

ii) Border Road Organisation (BRO)

BRO can propose separate budget head for Landslide Management measures for the route corridors under its supervision, if there is no such provision as yet.

iii) Department of Science & Technology (DST)

Department of Science & Technology, Govt. of India as a stakeholder in implementing the strategy can make it mandatory for researchers submitting new project proposals on LHZ mapping or those already carrying out landslide studies (using DST funds) to follow this strategy document and to work for only those areas which are still unattended.

iv) Mahatma Gandhi National Rural Employment Guarantee (MNREGA)

Provisions can be made in MNREGA scheme for structural mitigation of landslides in hill areas.

1.5.2 State Government Sources

State Governments of landslide prone states can make provision for landslide management head in the budget allocation of Public Works Department, Irrigation Department, Rural Engineering Services and Department of Disaster Management.

1.6 Monitoring mechanism

1.6.1 Formation of LHZ Monitoring Committee (LHZMC)

- LHZ Monitoring Committee (LHZMC) should be created under National Disaster Management Authority (NDMA) in consultation with nodal agency (GSI) and other expert agencies of Govt. of India and State Governments.

1.6.2 Roles and Responsibilities of LHZMC

- To identify the funding agencies and funding mechanism for preparation of user-friendly LHZ map, especially on 1:10000 scale.
- To prioritize target areas in consultation with NDMA, nodal agency and State Disaster Management Authorities (SDMAs of landslide prone states of the country).

- To monitor the progress of LHZ map creation at meso level.
- To ensure the dissemination of user friendly meso level LSZ maps to various stakeholders using web-based and app-based platforms.
- To facilitate SDMAs of respective states in the implementation of landslide management strategy and measures suggested in Meso level landslide management maps.
- To prioritize in consultation with experts and State Disaster Management Authorities (SDMAs of landslide prone states of the country) those regions of the respective states where 1:4,000 scale Micro level landslide susceptibility zonation will be taken up.

1.7 Recommendations

i. BMTPC's national scale (1:60,00,000) landslide susceptibility atlas be updated as and when new data and information is available. Methodology followed for preparation of BMTPC's national-scale (1:10,00,000 or smaller) landslide susceptibility map be continued as an optimum methodology for that particular scale.

[**Action**: BMTPC]

ii. On macro scale (1:50,000/25,000), GSI's terrain-specific methodology followed in NLSM project can be considered as an optimal methodology pertinent to that scale. NLSM maps need to be made available in mobile phones through app-based platforms.

[**Action**: Ministry of Mines (MoM)/GSI]

iii. Sectors for meso/large scale (1:10,000) landslide zonation preferably be chosen from the areas where previously created LHZ outputs by different agencies are available including those of NLSM, so that basic landslide and thematic database on macro scale can be used as base maps for this study.

[**Action**: BMTPC]

iv. Survey of India (SoI)/National Remote Sensing Centre (NRSC) for arranging supply 1:10,000 scale Topographic base maps for already-prioritized sectors, so that 1:10,000 scale landslide susceptibility zonation in those prioritized sectors in different parts of the country can be taken up as early as possible. [**Action**: SoI / NRSC]

v. There is an issue of methodology for landslide susceptibility mapping on 1:10,000 scale. GSI has already proposed one methodology and the same is under testing in two pilot areas in Eastern Himalayas. Start for taking up new 1:10,000 scale LSZ projects, initially in 10 out of the 47 identified/prioritised sectors by 2020, so that a robust methodology on this scale can also be developed. Attempts should be made also to execute conversion of 1:10,000 scale landslide susceptibility maps into proper landslide hazard and risk maps.

[**Action**: Nodal Agency (GSI) and other stakeholders]

2 Development of Landslide Monitoring & Early Warning System (EWS)

2.1 Introduction

Landslides are often triggered by intense rainfall or earthquake and it is observed that seismic high hazard zones and high rainfall areas coincide with high landslide hazard zones. Therefore, for early warning of landslides in India, it is pertinent to explore both the triggering factors i.e. precipitation and seismicity.

Occurrence of numerous rock/soil/debris slides/ flows in landslide prone regions, triggered by heavy precipitation during monsoonal precipitation (June to September) in most part of the landslide prone areas and during winter in Nilgiri hills, is of prime concern to local population and administration as these largely affect the economy and the very existence of population. A devastating example is the Kedarnath Disaster 2013, Uttarakhand where at least 5,000 people died in flash floods, glacial lake outburst flood and landslides triggered by extreme precipitation event during 14th-17th June 2013.

Theoretically all hill slopes can be considered as vulnerable to mass movements depending on the denudation processes, human intervention and the triggering mechanism. The high rainfall event in Mirik (2015) in Darjeeling Himalaya, in Uttarakhand (2013) in NW Himalaya and in Nilgiris (2009) in Western Ghats have triggered slope failures even in areas which were otherwise considered safe from landslide hazard. Such unanticipated events often result in extensive damages to life and property. One way to minimize the disastrous effect of such rainfall-triggered landslides is by timely forecasting the rainfall condition that can initiate mass movements. It is therefore required to establish a relation between the landslide trigger (rainfall) and the event with some assessment on its magnitude (intensity). This is very much possible through analysis of rainfall-threshold, which is in short the minimum intensity or duration of rainfall required to trigger a landslide.

World over many attempts have been made to use rainfall-threshold as an input for developing landslide early warning system (LEWS) for a large area. The data studied from 14 institutions from 8 countries in charge of one or several EWS have indicated that ideally EWS should be (1) robust, (2) simple, (3) redundant and (4) protected from power blackout and communication loss. Based on hydro-climatic data mainly rainfall data, climatic thresholds have been established in Korea, Hong Kong, United States, Canada, and elsewhere where abundant weather stations are located at different elevations and data on temporal occurrence of landslides allow statistically meaningful results. Attempts have been made towards prediction of landslide initiation using intensity-duration data for rainstorms. Inclusion of antecedent rainfall has further improved the results.

In developing countries such as in India, developing high-tech technique for few landslides is relatively easy, whereas making a relatively low tech methodology with high impact factor in terms of applicability is a real challenge that needs to be explored. One way forward is to integrate weather forecast and locally monitored rain gauge data into rainfall-threshold model to compute warning precipitation level which represents cumulative effect of complex interaction between precipitation, infiltration, evapo-transpiration and geotechnical properties (static and dynamic) of sub-surface strata. Although the underlying principles are very complex, the front-end could be very simple as attempted by the Nilgiri district administration in designing one such simple rainfall-threshold based warning system for shallow landslides.

In India, the problem of landslide trigger can be very complex as many vulnerable slopes lie in high seismic hazard zones. For example half of Uttarakhand and entire NE lies in zone-V that experiences number of earthquakes above

magnitude 4Mw every year. Earthquakes can have a dual role i.e. it may trigger co-seismic landslides directly as a consequence of earthquakes as observed during all major earthquakes of Himalaya and Northeast India. It is also further complicated by the factor that some of the high relief areas in Himalaya experience change in precipitation pattern as a consequence of climate change.

Therefore, the problem is really very complex. However, in order to treat the problem in a simplistic manner, it is recommended to deal with both the triggering factors separately. The whole concept of Early Warning System for landslides revolves around developing a cost effective methodology for predicting a condition in which landslides are most likely to occur. Therefore, as a first choice, it is worthwhile to explore the role of precipitation threshold for initiation of landslides with the help of examples from across the globe and recent initiatives by ISRO, GSI, CBRI, other academic and Government Departments. However, in order to predict the time of landslide event, attempts are also made to demonstrate recent advances involving extensive ground-based instrumentation to predict the time of landslide event and communicate the same in almost real time to the stakeholders.

2.2 Identified gaps

In Indian Himalayas, the poor network of weather stations and lack of high elevation rain gauges mars the collection of useful data that can help establishing meaningful relation. Orographic uplift results in greater rainfall at higher altitudes and secondly local slope aspect also influences as southern and eastern slopes receive more rainfall compared to the north facing slopes which are on the rain shadow region. Furthermore, accurate dates of landslides are seldom available due to sparsely population of the region and lack of media and official reporting of such events, although such reporting has improved in recent years.

Overall gap areas can be summarized as follows:

I. Well validated rainfall-threshold model is yet to be developed for all critical regions. For building rainfall threshold based model intensity-duration (ID) based threshold, date of past landslide events and corresponding representative daily/hourly rainfall data are required. In India, except for some cases, these datasets are not easily available for most part of the mountainous regions.

II. Threshold model itself does not provide information on the spatial occurrence of potential landslides; it has to be combined with landslide susceptibility to forecast spatio-temporal initiation of landslides.

III. Information on precise time of a landslide based on instrumentation and real time monitoring is mostly lacking.

IV. In India, safe shelter and alternate route maps for landslide hazard are often not available. These maps are to be prepared for important road sections and settlements.

V. Another important aspect that makes early warning ineffective is the lack of public awareness. This tends to reduce the risk by increasing awareness among the public with an aim to timely response to the warning when the disaster strikes.

VI. Communication of warning or risk to all concerned stake holders remains a challenge as most of the hilly area population either remains isolated, unreachable, non-responsive due to remoteness of the region or lack of awareness. Therefore, a multimedia approach involving internet portal, sms, social media, radio and print media is required.

VII. Access to secondary high quality rainfall prediction data, LHZ maps, and geotechnical data developed by other stakeholders at one platform.

VIII. Regulation and enforcement promoting monitoring of potential/ existing landslides that pose risk to life, economy and environment to large extents are weak.

2.3 Review of Work

A landslide early-warning system (LEWS) is envisaged as a system capable of modelling landslide occurrences and provide timely advance warning about the impending danger. It can be of different types, depending on the type of landslides, the target warning area and the communities to

be warned. It can be for an individual landslide where warning is based on movement sensors or for small areas for one or more landslides where warning is based on rainfall threshold or for a very large area using weather prediction. In order to develop a reliable LEWS, the processes leading to mass movement need to be understood and quantitatively measured for its spatial variation and temporal prediction.

In an international initiative under the SAFELAND project, Norway has developed a reliable LEWS and Slovakia has produced a guideline about general strategies to adopt. Most LEWS (81%) are based on displacement sensors and some on rainfall-threshold targeting a large area such as in Hong-Kong, Italy and USA. Once a threshold value is reached, almost all monitoring networks automatically notify alerts to operational units, using mainly SMS and/or e-mails services.

In the present context, a threshold may be defined as the rainfall, soil moisture, or hydrological conditions that when reached or exceeded, are likely to trigger landslides. In general, two types of rainfall thresholds are used; physical (process-based, conceptual) thresholds and empirical (historical, statistical) thresholds. Physical threshold models require detailed spatial information on the hydrological, lithological, morphological, and soil characteristics that control the initiation of landslides. These models can determine the amount of precipitation required to trigger slope failures, and the location and time of the expected landslides.

Empirical rainfall threshold models are evolved by studying the rainfall events that have resulted in landslides. Empirical rainfall thresholds may also be grouped in three broad categories based on the type of rainfall measurements: (1) thresholds that combine precipitation measurements obtained for specific rainfall events, (2) thresholds that include the antecedent conditions and (3) other thresholds, including hydrological thresholds.

Based on the extent of the geographical area, rainfall thresholds for rain-induced landslides with different types of precipitation measurements can be broadly subdivided into global, regional, or local thresholds based on their geographical extent. Global threshold attempts to establish a general ("worldwide") minimum level below which landslides do not occur, independent of local morphological, lithological, and land-use conditions and of local or regional rainfall pattern and history. Regional thresholds are defined for areas extending from a few to several thousand square kilometers of similar meteorological, climatic, and physiographic conditions. Local thresholds consider the local climatic regime and geomorphological setting and are applicable to single landslide or to groups of landslides in areas extending from a few to some hundreds of square kilometers (may be for local geographical area or for a highway corridor etc.). In some cases, distinction between regional and local thresholds is uncertain.

Landslide instrumentation and real-time monitoring can provide insight into the understanding of the dynamics of landslide movement. Real-time monitoring systems are intended: (1) to ensure high-quality data sets about landslide behavior; (2) to promote the evolution of better landslide monitoring by identifying the need for additional or different sensors to better detect changing field conditions; (3) for improved geotechnical designs or emergency actions aimed at mitigating landslide hazards and (4) also for advancing scientific understanding of active landslide behavior.

Real-time monitoring systems have been used throughout the world to detect or forecast landslide activity. Since 1985, researchers from the U.S. Geological Survey (USGS) have used real-time monitoring systems for regional warning systems and for recording the dynamics of hazardous active landslides or landslide-prone hill slopes. In India, there is hardly any successful attempt on real time monitoring of landslides. However, attempts had been made for a wired network of landslide instrumentation and monitoring in Mansa Devi Landslide, Haridwar, Uttarakhand during 2006. Subsequently, Central Building Research Institute (CBRI), Amrita Vishwa Vidyapeetham University (AVVU), Defense Terrain Research Laboratory (DTRL) and IIT Mandi in collaboration with NDMA have attempted instrumentation in different parts of country and early results as presented in various forums appear very promising.

2.3.1 Rainfall as a Triggering Factor: Concepts and Practices

In the present context this development i.e availability of methodology and initiatives for generation of medium to large scale landslide hazard zonation maps will be used as an advantage as these maps will further fine tune the regional rainfall threshold based modelling for LEWS. In the present context, outcomes of the Sub Group-I i.e., Generation of User-Friendly Landslide Hazard Maps will be integrated with LEWS.

It appears fairly simple to assume that higher rainfall will lead to landslides, however, there exists a lot of variability in terms of exact amount of rainfall, time of the rainfall-at the beginning of rainy season or later part of rainy season, size of the slide and underlying geological and geotechnical factors. This is mainly due to the fact that groundwater conditions are responsible for slope failures and are related to rainfall through infiltration, evapo-transpiration, soil characteristics, antecedent moisture content and rainfall history.

In simplistic term, the critical rainfall is the rainfall measured from the beginning of the event, i.e., from the time when rainfall intensity increases sharply, to the time of the occurrence of the landslide (Figure 1). The rapid increase in rainfall intensity results in a sharp break in the slope of the rainfall cumulative curve (Aleotti, 2004). This subtle change is to be captured by data analysis system to make any forecast about the onset of the landslide and also once the sliding starts, the rainfall requirement may undergo change and it may not be same as at the time of onset.

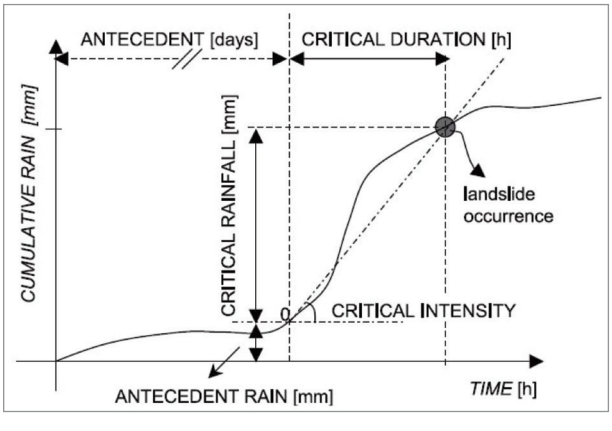

Figure 1. Main rainfall parameters used in the definition of landslide initiation rainfall thresholds (Aleotti, 2004).

The rainfall pattern is analysed through set of parameters. The Normalized Rainfall is the ratio between the event cumulative rainfall that triggers a landslide and the mean annual precipitation (MAP). The Normalized Critical Rainfall is the ratio between the event critical rainfall, and the mean annual precipitation (MAP). A threshold is defined as the minimum or maximum level of some quantity needed for a process to take place or a state to change. A minimum threshold defines the lowest level below which a process does not occur. A maximum threshold represents the level, above which a process always occurs, i.e., there is a 100% chance of occurrence whenever the threshold is exceeded.

For rainfall-induced slope failures a threshold may represent the minimum intensity or duration of rain, the minimum level of pore water pressure, the slope angle, the reduction of shear strength or the displacement required for a landslide to take place.

The most commonly investigated rainfall parameters are: (i) Total (cumulative) rainfall; (ii) Antecedent rainfall; (iii) Rainfall intensity, and (iv) Rainfall duration. Various combinations of the listed parameters have been attempted. Thresholds have been defined considering: (i) Rainfall intensity; (ii) Maximum rainfall intensity for the duration of the event; (iii) Rainfall intensity at the time of the slope failure; (iv) Mean rainfall intensity for the event; (v) Duration above a pre-defined intensity level; (vi) cumulative rainfall, with or without the exact indication of the time of the slope failure; (vii) Intensity or cumulative rainfall normalized to MAP; (viii) Rainfall intensity normalized to the ratio between MAP and the yearly number of rainy days; (ix) Antecedent rainfall, for different time intervals before the occurrence of the event, or the starting time of the event; and (x) Daily rainfall versus antecedent soil moisture index.

The threshold based EWS is most cost-effective for a large area with instability problems where there is no possibility to monitor each landslide individually. Usually such LEWSs are much more reliable over broad regions than at the slope scale because thresholds are calibrated on landslides that happened in the past over a broad region, rather than at specific sites. However, these can

be extremely useful if regions are smaller and models are well calibrated using good database on precipitation and landslides.

Recently, Geological Survey of India with British Geological Survey is working on a project called LANDSLIP (Landslide Multi-Hazard Risk Assessment, Preparedness and Early Warning in South Asia: Integrating Meteorology, Landscape and Society). The project aims to integrate Meteorological, Landscape and Social dynamics for developing a relevant and effective tool for landslide multi-hazard risk assessment and to develop an early warning system for spatial scales from slope to catchment and temporal scales from a day to month. Two pilot areas: Nilgiri hills in Tamil Nadu and Darjeeling hills in West Bengal have been taken for LANDSLIP project which will be completed by 2020.

2.3.2 Earthquake triggered or seismicity induced landslides (SIL)

Earthquake triggered or seismicity induced landslides (SIL) can be major ancillary hazard associated with earthquakes in hilly region. For monitoring the earthquake/ground vibration triggered landslides, bore hole seismometers can be used as a part of wireless sensor network (WSN) based ground instrumentation and real time monitoring system.

2.4 Monitoring Mechanism

Monitoring of landslides with appropriate technology is one of the most challenging task of landslide disaster mitigation efforts. Using both remote sensing and ground based instruments; the slope condition and early sign of movement can be detected and thus can save life and property by enabling timely evacuation. Secondly, the efficacy of remedial measures/structural intervention can be assessed based on the movement of slope. There are several methods of landslide monitoring based on emerging space and ground based technology.

i) Monitoring of Active Landslides
ii) Monitoring of Old Landslides
iii) Monitoring of Landslide Hazard Zones
iv) Slope monitoring using UAV
v) Slope Deformation Monitoring Using GNSS
vi) Slope Monitoring Using Terrestrial Laser Scanner
vii) Slope Deformation Monitoring Using DInSAR
viii) Wireless Sensor Network (WSN) Based Ground Instrumentation and Real Time Monitoring
ix) Slope Monitoring Using Dynamic Modelling
x) Slope Monitoring Using Geophysical Techniques

2.5 Recommendations

2.5.1 Rainfall Threshold based Landslide Early warning System (RT-LEWS)

- Database on rainfall derived from satellite and ground based observation need to be compiled and analysed to understand variability in a region vis-à-vis landslides.

  [**Action**: Ministry of Mines (MoM)/GSI in collaboration with IMD and in coordination with States]

- Road/railroad maintenance records of Border Road Organisation (BRO) and railway department in Nilgiri hills provide information of date and spatial distribution of landslides in the form of debris accumulated on the road, but is restricted to only defined road/ railway sectors. The type of data available with them also requires intense field validation before making them useable for threshold modeling.

  [**Action**: BRO, NHAI, PWD, Ministry of Railways (MoR) and other stakeholders]

- Compilation of landslide database with information on typology, location, date and time of occurrence. High resolution satellite images need to be used to prepare the spatial database with good accuracy.

  [**Action**: Ministry of Mines (MoM)/GSI in collaboration with NRSC and in coordination with concerned State Governments]

- Development of rainfall threshold models (I-D and antecedent rainfall based) using available information (rainfall and landslide) from IMD, BRO and other sources for regional and local level LEWS. It is envisaged to use I-D and RT based models using data mining and statistical approaches as demonstrated by IIRS, CBRI and GSI.

  [**Action**: Ministry of Mines (MoM)/GSI, CWC,

other expert institutions and stakeholders in collaboration with States]

- Rainfall prediction by the Numerical Weather Prediction (NWP) models to increase the lead time of early warning. The NWP models can provide very accurate rainfall forecasts 72 hours in advance over the mountainous regions.

  [**Action**: Ministry of Mines (MoM)/GSI, other expert institutions and stakeholders in collaboration with States]

- In order to address landslides induced by extremely localized high precipitation events known as "Cloud Burst", it is desirable to increase the density of automated rain gauges (ARGs) or AWS in hilly regions with appropriate arrangement and analyse it on real time hourly data or data at minute's interval using DART and I-D model.

  [**Action**: Ministry of Mines (MoM)/GSI in coordination with IMD, CWC and other stakeholders in collaboration with concerned States]

- Wireless networking of all landslide monitoring stations and establishment of real time rainfall monitoring control room. Also, development of early warning communication mechanism.

  [**Action**: Ministry of Mines (MoM)/GSI in collaboration with IMD and in consultation with TAC and NDMA]

- Implementation of rainfall based landslide early warning system for regional and local use.
  - ➢ Alarm/broadcasting system for traffic control on hill roads/highways during monsoon seasons.
  - ➢ Alarm/broadcasting system for community use in hill habitats for landslide risk reduction.

  [**Action**: Ministry of Mines (MoM)/GSI in collaboration with IMD and in consultation with TAC]

- The threshold model, as established for different regions, can be used to calculate probability of landslides based on predicted rainfall and its accuracy would be as good as rainfall prediction accuracy which is improving significantly due to better weather forecast models. Rainfall forecast can improve significantly by using Doppler Weather Radar (DWR), which can further help the landslide prediction and early warning.

  [**Action**: Ministry of Mines (MoM)/GSI in collaboration with IMD and in consultation with TAC and other stakeholders]

2.5.2 Ground Instrument based landslide early warning system (GI-LEWS)

- Selection of problematic severe landslides for instrumentation in different parts of hill states.
- Preliminary deformation monitoring using GNSS.
- Investigation of landslides and finalization of scheme of landslide instrumentation using cost effective smart techniques including space technology.
- Wireless sensor network (WSN) based instrumentation and real time monitoring of landslides.
- Greater emphasis should be on MEMS based sensors (e.g. accelerometer, soil moisture sensor, force sensor, tilt sensor etc.).
- Periodic data capture and analysis to develop multi-parametric threshold models for landslide early warning.
- Validation of landslide early warning thresholds and models.
- Development of early warning communication mechanism.
- Implementation of instrumentation based landslide early warning system for societal use.

  [**Action**: Ministry of Mines (MoM)/GSI in collaboration with other stakeholders and in consultation with NDMA]

2.5.3 Seismicity induced landslide EWS (SI-LEWS)

- Selection of study area and compilation of seismic data and early records of SIL.
- Preparation of surface geological map and

good quality slope map from DEM.

- Geotechnical characterization of surface geological materials.
- Seismic induced landslide (SIL) modelling for simulated events and result validation.
- Deployment of MEMS based seismometers and accelerometers for real time warning.

[**Action**: Ministry of Mines (MoM)/GSI in collaboration with NCS-MoES, IMD and other stakeholders]

2.6 Implementation Strategy

In order to develop a well-established threshold based EWS for a large area in India, it is proposed to provide a framework that can be adopted depending on the site condition and requirement. The LEWS is envisaged at three levels: RT/I-D based models (Local level and regional level). At critical locations LEWS is to be developed with ground instrumentation.

In this regard it is very important that appropriate Memorandum of Understanding (MoU) may be signed between the State Disaster Management Authority (SDMA) and the Institute/Organisation having the expertise on such instrumentation and real time monitoring of landslides for development of LEWS.

2.6.1 Development of RT and I-D Based Models for LEWS

Based on intensity (I) and duration (D) relationship, threshold can be established. The main advantage of this relationship is that for a given intensity, hourly prediction can be made. While the Rainfall Threshold (RT) model provides information on landslide day, the I-D model will provide information after how many hours, the landside is going to take place. Both these models will complement to each other in terms of prediction. Although these are derived from the same data sets, both capture two different dimensions of precipitation.

2.6.2 Issue of Warning

The warning can be issued based on the actual threshold calculated with rainfall forecast. As the rainfall is dynamic, so also RT/I-D and based on exceedance of threshold values corresponding to landslide phenomena in the past, the values can be interpreted in terms of severity. In order to illustrate the above concept, methodology as envisaged by GSI can be cited (Figure 2).

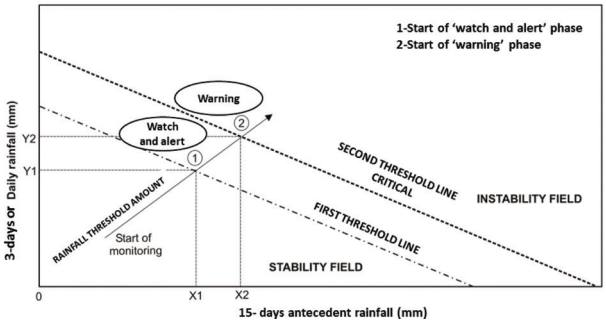

Figure 2. Schematic diagram that can be used to issue warning of rainfall-induced landslides based on rainfall threshold.

During 'watch and alert' phase one has to be watchful and look for further information or if the precipitation increases then one should take action appropriate for 'warning' phase. During warning phase, stakeholders should be ready for evacuation in high or very high hazard zones. In fact after the 'watch and alert' warning the people should be on the alert, and start looking for signs of instability to evacuate.

2.6.3 Challenges of LEWS

There can be several reasons which make the implementation of warning systems difficult. These include: limited resources, lack of precise rainfall forecast, lack of geotechnical data, lack of communication network in remote areas and lack of public awareness about potential landslide risk and actions to be taken during different stages of warning. Besides these practical difficulties, uncertainties in the warning system like false alarms (warnings that are not followed by landslides) further make its implementation difficult.

2.6.4 Implementation of LEWS: Action plans

a) Short Term (1-2year)

I. Development of RT-LEWS (including I-D model) using available information from

IMD, BRO and other sources for regional and local levels.

II. Development of SI-LEWS for selected regions and validation with past events.

III. Selection of sites for GI-LEWS and starting of preliminary analysis using RS and GNSS observation on activity and movement of landslide.

IV. Set up a regular monitoring system using RS/ GNSS/UAV/Geophysics/Community based approach.

V. Capacity building and awareness generation on all types of LEWS and landslide monitoring.

b) Medium Term (3-4 year)

I. Increase in the density of automatic rain gauges identifying the gap locations in hilly regions

II. Improve the RT-LEWS based on AWS and better landslide inventory.

III. Selection of sites for instrumentation for SI-LEWS.

IV. Wireless networking of all these rain gauge stations and establishment of real time rainfall monitoring control room to communicate the early warning/fore warning information to the competent authority and the public concern.

V. Capacity building and awareness generation on all types of LEWS and landslide monitoring.

c) Long Term (5-6 year)

I. Wireless sensor network (WSN) based ground instrumentation and real time monitoring of landslides.

II. Development of early warning communication mechanism.

III. Implementation of GI-LEWS.

IV. Feedback analysis and LEWS improvement.

V. Capacity building and awareness generation on all types of LEWS and landslide monitoring.

2.6.5 Institutional Arrangements

I. Cluster Approach: In which, an agency with known expertise and local presence can be the lead agency and others organizations (GSI, CBRI, DTRL, Amrita University, IIRS, IITs etc.) could join as team members to provide technical guidance.

II. Capacity building: For capacity building of technical personnel of implementing agencies, industry in collaboration with other agencies can design and organize specialized training programmes in a sustainable manner.

III. Ownership issues: The stakeholder organization or department should own and maintain the system with commitment for upgradation and improvement. It involves recruitment of appropriate manpower, budget allocation and capacity building and net working with research organisations.

IV. Industry development: To involve industry and provide right kind of atmosphere for innovation and risk taking efforts. The ultimate aim is to develop new techniques for LEWS that is not only suitable for Indian region but also the know-how and sensors can be exported abroad as embedded systems.

2.7 Financial Implications

LEWS based on ID and RT will require mostly collection of data and analysis of the same with validation for at least 3-years. Cost and time optimization can be worked out based on single site or multiple areas.

LEWS of Wireless sensor network (WSN) based ground instrumentation and real time monitoring of landslides will require time duration of 24 months. Cost and time optimization can be worked out based on actual site.

SI-LEWS depending upon the level of instrumentation and modelling, can be set up in 1.5 years time frame at a nominal budget including cost of one JRF per region. Final cost and time optimization can be worked out based on actual area of study.

Financial provisions for allocation of budget should be made for capacity building and awareness programmes related to development, implementation and popularization of LEWS. This should be a continuous activity and therefore, budget should be available in a long term basis.

3 Awareness Programmes

3.1 Introduction

The role of concerned State/UT's authorities and local communities are essential not only in the preparedness and mitigation phases of disaster management, but, also in the emergency situations during the event. Awareness and capacity development programmes will be successful, if involvement of local communities and authorities such as District Administration, Panchayati Raj Institutions and local communities are maximized.

There is an immense need of effective cooperation and coordination amongst various stakeholders for the implementation of activities in the landslide affected areas. Not only trickle down but also bottom to top approach will be beneficial to achieve the success in making landslide Disaster Risk Reduction (DRR) system in India. This approach would be helpful in the proper implementation and functioning of structural and non-structural mitigation measures at grass root level. Awareness generation programmes by identified Department / Institute, Agencies such as Geological Survey of India, ATI's, NGO etc. will be conducted on the basis of landslide awareness modules, packages and other Information Education and Communication (IEC) material will be developed by Expert Department / Institute, Agency, NGO's etc. on different themes.

Mass awareness generation programmes through the electronic and print media, multimedia, interactive meets, mock drills, distribution of handbills and posters in local languages interlinked with Digital India campaign are indispensable for disaster preparedness and mitigation. State Disaster Management Authority (SDMA) / State Government may take pro-active measures and initiatives in collaboration with other stakeholders for minimizing losses.

3.2 Review of Work

In India, the main cause of the heavy losses during landslides is the lack of awareness among the people including local residents and tourists about the first aid, safety routes, warning signs and first response to landslide emergency situation. To study the level of awareness and preparedness level of communities and government is of utmost importance.

After the successful implementation of the GoI-UNDP Disaster Risk Management Programme (2002-2009), the Government of India, with the support from UNDP is implemented the GoI-UNDP Disaster Risk Reduction Programme (DRR) from 2009-2012 with $12 Million support. The program was focused on strengthening the institutional structure to undertake disaster risks reduction and to develop preparedness for recovery.

A road map had been prepared by Natural Resource Data Management System (NRDMS), Department of Science and Technology for Landslide for Landslide Risk Management in India in the year 2010, covering the mechanisms of Landslide Risk Assessment by Landslide Hazard Zonation Mapping and by building capacity of indigenous communities living in the area of susceptible to landslide hazard. In the road map, efforts have also been made for landslide risk mitigation by learning from their previous events and shared experiences in the same regions or other. Early warning against landslides based on robust prediction, and Retrofitting of problematic slopes and unsafe buildings is essential. Landslide education and training, and Landslide Response, Rescue and Reconstruction are also some of the other important steps included for risk mitigation in the road map of Natural Resource Data Management System (NRDMS), Department of Science and Technology.

The module on "Comprehensive Landslides Risk Management" which has been developed by National Institute of Disaster Management (NIDM), Ministry of Home Affairs covers five days rigorous training course focusing on transmitting basic and requisite knowledge/skills needed by stakeholders of the society at various levels in the field of landslide management.

Asian Disaster Preparedness Centre (ADPC) in the Program for Hydro-meteorological Disaster Mitigation in Secondary Cities in Asia has taken help of three different case studies of Baguio City in Philippines, Patong City in Thailand and Kaluthara District, Sri Lanka by using risk assessments to reduce landslide risk. These three different case studies demonstrate how to reduce the impact in landslide hazard prone areas. Identifying the mapping process is the first step for landslide risk analysis, to establish zones in terms of degree of risk, and locate the landslide hotspots within the area. Further steps include monitoring the land movements and the rainfall patterns is then crucial; in each study area, scientific agencies have focused on the local communities and schools participation and using their traditional practices as part of their involvement in the landslide risk mitigation process. The good governance system is one of the substantial foundations for fostering an efficient policy framework for different stakeholders to adopt and implement together a coherent strategy of landslide risk adaptation.

3.3 Identified Gaps

The existing work provides a comprehensive work on the issues of landslide risk reduction. But it is also significant to identify the gaps at national and international level due to which things have not been getting implemented at grass root level.

3.3.1 National Level

In all the susceptible regions, local authorities have started to engage themselves, following up and implementing policies to build a comprehensive landslide risk mitigation framework, to reduce the exposure and the related vulnerabilities of the population. But still it provides the need to engage local communities also, because at the end of the day they are particularly susceptible and policies are formed for their betterment first. Bringing all the stakeholders of society together helps to ensure the durability and the expansion of landslide risk reduction in the society and also other geographical areas by involving the local people considered as catalysts of change. Major gaps identified are as follows:

(i) **Classification of the States which are prone to landslides according to severity.** The states will be classified into the following three categories based on the Landslide Hazard Zonation Map.

- State I - Very High & High Hazard Zone
- States II - Moderate & Moderately High Hazard Zone
- States III - Low & Very Low Hazard Zone

(ii) Need to study the socio-economic profile of the communities residing in these areas: There is a need to gauge the level of awareness among the people inhabiting these areas about disasters in general and landslides in particular and to determine the information requirements of the people inhabiting these areas.

(iii) Awareness programmes and campaigns are to be conducted on regular basis. A major drawback of the system is that awareness programmes does not reach the community vulnerable to the disaster. A comprehensive awareness outreach is to be established, so that it can benefit the society (especially the communities at risk) in understanding and implementing the prevention and mitigation measures.

3.3.2 International Level

The active engagement at the global level, linking and integrating their best practices by supporting technical experts tend to strengthen the knowledge dissemination channels on landslide risk mitigation and encourages further awareness among all the different stakeholders on the landslide risk situation. Subsequently, the disaster risk adaptation mechanisms can be expanded swiftly and more easily to other type of risks.

Today there is a crucial need of improved recommendations for improved recognition and

smart management of landslides within rural-urban corridors of susceptible zones. It can be recognised that many of the recommendations at national and international level are both idealised and generalised for particular locations and there will be valid reasons in specific cases where they cannot be applied. The implementation of some of the recommendations will require a significant degree of institutional effort in collaboration with support at local level. For outweighing financial hurdles, it would be necessary to convince the authorities involved that the benefits outweigh the overall costs and logistical difficulties.

3.4 Recommendations

One of the main tasks before us is to focus on prevention in disaster management at all levels. The culture of awareness generation and preparedness must be disseminated; so that all people in the society can become alert and aware in case of an emergency or before the disasters strikes to take some preventive measures. In India, a paradigm shift from post disaster response to pre disaster prevention, preparedness and mitigation strategy should be focused on. There is an immediate need to make local people aware about landslides to reduce losses.

The development and enhancement of awareness generation and preparedness requires following necessary steps to be taken as under:-

3.4.1 Involvement of local masses

- The response time is poor due to difficult terrain and accessibility in mountainous regions of India. Therefore, involvement of local community, inhabited individuals, youth clubs, NGOs in awareness programmes will improve knowledge associated through capacity building to fight / self-help during and after any event.

  [**Action**: Ministry of Mines (MoM)/GSI, SDMA's/DDMA's and other expert institutions and stakeholders]

3.4.2 Enhancement of education focusing upon youth especially

- A simplistic course (with informatics) at school level may be introduced which must elaborate do's and don'ts to prevent/ mitigate any type of landslide situation. A compulsory course on disaster risk reduction (as Environmental Sciences at Graduation Level) may follow at University level.

  [**Action**: MHRD, UGC, IIT's, Universities, other academic institutions, States and its concerned Departments such as Education Department etc. in collaboration with NDMA/NIDM]

- Landslide management and awareness including geo-climatic region, landslide characteristics, landslide vulnerable zone, their participation in the times of landslide etc. of their own particular area should be taken as an academic compulsory subject for the local children from primary school level education.

  [**Action**: State Governments in collaboration with SDMA's and other stakeholders]

- Community Education Programme of 10 to 15 days may be initiated by the governmental agencies. The specialists like the staff of NDMA/SDMA and NIDM may arrange training cum education programme for inhabitants particularly the elderly, woman, youth, physically challenged etc.

  [**Action**: NDMA, NIDM, SDMA's (ATI's) / DDMA's and other stakeholders in consultation with TAC and LHZMC]

3.4.3 Involvement of educated mass for creating awareness amongst local people and school children

- The land use planner, urban planner should make the local people understand about the importance of landuse planning. But deforestation, urbanization, industrialization, maximum use of resource, heavy building construction and engineering structural work etc. increases the landslide vulnerability. Thus, proper scientific landuse planning and ban on biodegradable materials is necessary. The scientist and engineer should arrange awareness camp to increase geological, geo-hydrological investigation practice for contractor.

[**Action**: Ministry of Mines (MoM)/GSI, SDMA's (ATI's)/DDMA's and other expert institutions and stakeholders]

- Organize village wise training cum workshops for youth / elderly people on topic such as "Procedure to rescue oneself, family and neighborhood in the time of landslide".

  [**Action**: Ministry of Mines (MoM)/GSI, NDMA and SDMA's / DDMA's]

3.4.4 Promotion of latest technology and techniques.

- Geologist, engineers and other disciplines related to the field of landslides must be exposed to the latest development in the domain of landslides investigations and management that are globally followed on a regular basis.

  [**Action**: Ministry of Mines (MoM)/GSI, NDMA, NIDM and SDMA's (ATI's) / DDMA's]

- The early warning system can reduce the maximum losses due to landslide hazard. Monitoring and analysis of natural parameters such as rainfall patterns and water absorption, land movements and slope evolution is critical to landslide risk mitigation.

  [**Action**: Ministry of Mines (MoM)/GSI in collaboration with IMD and other expert institutions in coordination with SDMA's / DDMA's]

3.5 Implementation Strategy

The strategies which can be adopted across the country are as follows:-

A. Short Term

1. Automated SMS and e-mail service: In view of this, NDMA can collaborate with the various government and private travel agencies including Indian Airlines, Indian Railways and mobile network operators to send automated SMS and e-mail messages on precaution to be taken while travelling in the landslide prone areas at the time of booking of tickets to these areas.
2. Toll free number for landslide reporting: Each state in the very high and high risk zonation can initiate a toll free number for landslide reporting. Upon receiving reports of landslide / early signs of landslide from people.
3. Creation of common signage for landslides prone area across the country: A common signage for landslide prone area can be designed. This signage can be put in landslide prone areas across the country.
4. Computer game for disaster: NDMA in collaboration with expert agencies / Institutes for computer application can design computer and mobile games on disaster management.
5. Use of local mass media: A well designed mass media campaign (both print & electronic) can be undertaken in these states. The campaign must be designed in the local languages.
6. Use of posters and hoardings: Posters and hoardings on the various aspects of awareness regarding landslide can be designed and displayed at all important public places. The campaign material should be translated into local languages.
7. Use of Global Disaster Preparedness Disaster Response Apps: There are number of globally recognized disaster preparedness disaster response apps serving the needs of people affected by disasters. These top mobile apps could prove fruitful in providing assistance to aid workers and volunteers in better preparedness and respond to landslide and other disasters such as American Red Cross Apps, Disaster Alert (Pacific Disaster Center's World Disaster Alerts) App, Global Emergency Overview (ACAPS) App, Humanitarian Kiosk (United Nations), Federal Emergency Management Agency (FEMA) App, etc.

B. Medium Term

1. Awareness through community radio: The local community radio can broadcast programmes on awareness. It can also transmit early warning messages regarding the occurrence of landslides in the area.

2. Design of animated character for spreading awareness on disaster management (including landslides): An animated character 'Sabu' (a baby rhinoceros) can be designed in partnership with computer animators.
3. Publication of awareness campaign on landslides using the print and electronic media across the country: Awareness campaigns on landslides can be conducted using the print and electronic media. The campaign should be in the national and regional newspapers, radio and TV channels.
4. Creation of a disaster management application: NDMA in collaboration with Indian Institute of Technology (IIT) can design a computer application for disaster management. The application can be used to know about the latest information on disasters (including landslides) across the country.
5. Awareness through documentary: The National Disaster Management Authority (NDMA) should initiate a programme on power point documentary/presentation for Government organisation, School and Hospital organisation, Soldiers, NGOs, Local nodal agencies, Local club, and local people focusing on the role and responsibility before, during and after the landslide disaster.
6. Creation of village task force: The not-for-profit organizations should constitute a village task force in each village of these states. The members of the task force should be made aware of the various aspects of landslide mitigation and post-landslide activities.

C. Long Term

1. Awareness programme on landslide hazard: Government (National/ State) has also emphasized on a robust awareness programme for landslide hazard. Public awareness is being enhanced about signs and events that manifests that a landslide is imminent so that personal safety measures may be taken. Some of these signs include:
   i) Springs, seeps, or saturated ground in areas that have not typically been wet before.
   ii) New cracks or unusual bulges in the ground, street pavements or sidewalks.
   iii) Soil moving away from foundations, and ancillary structures such as decks and patios tilting and/or moving relative to the house.
   iv) Broken water lines and other underground utilities.
   v) Leaning telephone poles, trees, retaining walls or fences.
   vi) Sunken or dropped-down road beds.
   vii) Rapid increase in a stream or creek water levels, possibly accompanied by increased turbidity (soil content).
   viii) Sudden decrease in creek water levels even though it is still raining or rainfall has recently stopped.
2. Use of traditional art forms/traditional knowledge: Due to modernization and tech-savvy nature of 21st century generation, old traditions disaster management practices are dying up. Therefore, it is necessary to document and disseminate old traditional best practices available in mountain regions of India through community participation in trainings. Traditional art forms are important mediums of awareness generation. Traditional knowledge and modern technologies are also useful in designing landslide Early Warning System (EWS).
3. Awareness through Participatory Approach: The planning and implementation process is recommended in order to maintain sustainability of the programs launched by the administration for disaster management. It is necessary that the government and the communities together evolve a joint action plan aimed at enhancing community education and development of community leadership. The elements of participatory learning can be applied at different levels such as organizational level (headquarters, branches, schools, businesses, workplaces), community level (village, town, cities) and

population level (marginalized, vulnerable sections).

4. Landslide education plan: An illustrated booklet with information on landslide awareness can be prepared in local languages. This can be circulated among the PRI members, Front Line Health Workers (FLHW), School Teachers, Youth Leaders, members and other important stakeholder groups in these areas.
5. Involvement of Not-for-Profit Organisations: NDMA should identify not-for-profit organisations to undertake the awareness building activities in these States. The organisation should be asked to submit a targeted awareness generation plan.
6. Awareness among school children, their parents and teachers: The not-for-profit organisations can organise sessions for school children, their parents and teachers from Class IX onwards on various aspects of landslide occurrence and their mitigation. A one day training module can be designed for the participants.
7. Awareness among local youth: The not-for-profit organisation can hold a day long awareness generation camp with the members of National Cadet Corps (NCC), Scouts and Guides, and National Service Scheme (NSS) volunteers. These camps should be conducted in coordination with the state and district teams of these organisations.
8. National Data Centre on Landslide: It would integrate various data sources, a geo-portal to address the data needs and thus, enable an effective response.
9. Awareness among members of Panchayati Raj institutions: On similar lines; the not-for-profit organizations can also hold a one day awareness generation workshop for the PRI members of the various panchayats in the district in the district headquarter. The Community Based Family Disaster Preparedness and mitigation (CBFDP) is a process to capacitate communities to prevent, mitigate and cope with disasters effectively
10. Awareness among policy makers and government officials: The policy makers are key stakeholders in disaster management. State Disaster Management Authority (SDMA) can hold workshops with policy makers and government officials of all departments to reinforce their role in ensuring that people conform to the various land use policies.
11. Climate Change related landslide risk management: The past incidences clearly indicate the high frequency as well as intensity of the hydro-meteorological hazards in the mountain region such as heavy rainfall, landslides, riverine floods, cloud burst, Glacial Lake Outburst Floods (GLOFs), droughts etc. Therefore, local communities require awareness, specialized training and right information to cope up with disasters in the mountains.

3.6 Financial Implications

Disaster prevention is indeed, more cost effective than disaster response and rehabilitation. The focus should thus, be on disaster preparedness and mitigation. The allocation of fund is depending upon the availability of capital for landslide and other associated risk management in the concerned State/UT and it will vary from one State to other.

3.7 Monitoring Mechanism

Monitoring is an essential part of any project / programme, therefore following steps are required for proper implementation of strategy at ground level:-

1. Utilization certificate as per GFR
2. Progress Report (time to time)
3. Minutes of meeting to be provided.
4. Audit & Inspection
5. Feedback from target groups

The landslide awareness programmes must be monitored regularly so as to implement the strategy based on feedback, challenges and technological and other development solutions.

4 Capacity Building & Training of Stakeholders

4.1 Introduction

Majority of landslide prone habitations are located in the hinterlands of the Himalayan States, northeastern States and also on the Eastern and Western Ghats of southern and south western coastal States of the country. Hence, it becomes a very cumbersome task for the district administration and response teams including NDRF and SDRF teams to reach the site of disaster within the short span of time due to remoteness and ruggedness of the terrain and poor infrastructure facilities. Higher incidences of landslides during rainy reason and prevalent bad weather conditions coupled with poor visibility make it difficult to carryout rescue operations using helicopters. Hence, local inhabitants by default become the first responders to the disaster. Scientific observation in north Sikkim and Garhwal regions in the Himalayas clearly reveal that there is an average of two landslides per sq. km. In the Nilgiris, in 1978 alone, unprecedented rains in the region triggered about one hundred landslides, which caused severe damage to communication lines, tea gardens and other cultivated crops. The circumstances cited above necessitate for strengthening a community based approach for coping up with the disasters including the landslides in these areas.

4.2 Review of Work

During the past decade capacity building and training of all the stakeholders in Disaster Management has gained momentum throughout the world. However, there are huge gaps in capacity building initiatives and training programs being developed and run in India. Initiatives are required in the form of national programmes like capacity building in Earthquake Risk Management i.e., National Programme for Capacity Building of Architects in Earthquake Risk Management (NPCBAERM) and the National Programme for Capacity Building of Engineers in Earthquake Risk Management (NPCBEERM) were launched by the Ministry of Home Affairs (MHA), Govt. of India in the year 2004.

4.2.1 National Level

In India, the need for Capacity Building and Training of the stakeholders in landslide risk management was realized not long ago. The realization came after two tragic events of Okhimath and Malpa landslides during in August, 1998. Following are some of the major initiatives taken in many of the landslide prone states (mainly Himalayan states) of the country:-

(i) On 23 December 2005, the Government of India enacted the Disaster Management Act, which envisaged the creation of NDMA, headed by the Hon'ble Prime Minister, and SDMAs headed by respective Chief Ministers, to spearhead and implement a holistic and integrated approach to Disaster Management in India.

(ii) NDMA has released a Guideline on "Management of Landslides and Snow Avalanches" in June, 2009 to adopt a holistic approach for mainstreaming landslide DRR, besides strengthening of the State machinery and providing all necessary support to the concerned States and UT's.

(iii) Disaster Management Committees at District, Tehsil/Block and Village level were constituted with various names such as District Disaster Management Committee (DDMC)/District Emergency Operations Group (DEOG); Tehsil/Block Disaster

Management Committee (TDMC/BDMC). Further, the Village Disaster Management Committees (VDMCs) were also constituted in many landslide prone villages.

(iv) Under MHA (GoI) - UNDP sponsored Disaster Risk Management (DRM) Programme, the multi-hazard prone districts were selected for Training and Capacity Building in Disaster Management.

(v) A number of training and workshops have been organized by various States at State, District, Block and Village level on various aspects of Disaster Management.

(vi) Disaster Management Action Plans (DMPs) at State and District level were also prepared on the basis of discussions with State and District Disaster Management Committees. Offices of Relief Commissioner and Department of Disaster Management of the respective states played a pivotal role of facilitator in this initiative.

(vii) National Institute of Disaster Management (NIDM) also conducts many programs on Landslide Risk Management. Department of Science and Technology (DST), Government of India has also been working on National Capacity Building in the area of Landslide Hazard and Risk Assessment. Wadia Institute of Himalayan Geology (WIHG), Dehradun also conducts training programmes on landslide DRR.

(viii) The Government of Mizoram and Geo-Hazards Society carried out a comprehensive fourteen-day 'Geology Field School' for practicing geologists from Mizoram and nominated representatives from Assam, Tripura and Manipur.

(ix) Indian Academy of Highway Engineers (IAHE) conducts regular training programmes on landslide mitigation and rock fall, for the Engineers & highway sector professionals of Central Government organizations, State Government organizations, Public sector units, private sector, stakeholders of multi-lateral agencies like World Bank, Asian Development Bank, etc.

(x) Constituent establishment of CSIR such as Central Building Research Institute, Roorkee organizes many training programs on landslide management including national level training programs on landslide control measures.

(xi) CSIR- Central Road Research Institute also organizes a regular (Annual) training programme and workshops like "Climate Change and Landslide". Other than that it also conducts the customized training programs as per the need of the stakeholders like PWD, BRO, etc.

(xii) Indian Institute of Remote Sensing (IIRS), Dehradun; National Remote Sensing Centre (NRSC), Hyderabad and State Remote Sensing Centers in particular have included Remote Sensing, GIS and GPS based landslide studies in their various training programs on Disaster Management.

(xiii) Uttarakhand Government during the district level training workshop for local stakeholders of District Disaster Management Committee (DDMC) at Gopeshwar had used their training lessons on field in Chamoli district of Uttarakhand in year 2004 where the landsliding zone were structurally mitigated and made stable.

4.2.2 International Level

International Program on Landslides Risk Reduction by UN and other agencies contributed significantly for developing institutional capabilities at different levels. Further, the regional institutes like Asian Disaster Preparedness Centre (ADPC) – Bangkok, Asian Disaster Reduction Centre (ADRC), Kobe and Disaster Prevention Research Institute (DPRI), Kyoto have contributed for joint actions for landslides risk reduction by different countries.

National Landslide Mitigation Strategy of U.S. also emphasizes on building resilient communities by providing training for federal, state and local emergency managers on landslide hazards, preparedness, response and recovery. Further, it also lays emphasis on developing a coordinated landslide rapid response capability to assist local state and federal emergency managers in determining the nature of landslide hazards and

the extent of ongoing risks (USGS, 2000). The World Bank in 2013 introduced MoSSaiC (Management of Slope Stability in Communities) vision for engaging policy makers, project managers, practitioners, and vulnerable communities in reducing urban landslide risk in developing countries.

4.3 Identified Gaps

Various gaps pertaining to different aspects of capacity building of stakeholders and the community in landslide DRR have been identified and elaborated below:

4.3.1 Need of Comprehensive Training Need Assessment (TNA):

A Comprehensive training needs assessment at various levels of administrative hierarchy viz. National, State, District, Tehsil, Block and Village level needs to be conducted in all landslide prone states. Different training modules should be prepared for each level, and the frequency of training in each region should be mentioned as part of a capacity building action plan.

4.3.2 Gaps pertaining to technological inputs in training programmes on landslide DRR

Trainees viz. disaster managers, planners, decision makers, official of line departments, engineers, NGO and CBO representatives and locals participating in a training programme on landslide DRR require a precise site specific overview of landslide hazard, causes, vulnerability, risk and required mitigation measures. This type of information can be provided to the stakeholders only through meso and micro level LHZ/LSZ maps. Scientists and social workers emphasize the need for user friendly validated maps of landslide hazard, data inventory, models etc. in the hands of disaster managers.

Capacity building programmes on GIS mapping of landslide areas are also required to enable Departments of Geology in the State Governments (DGM) to develop landslide hazard maps in scales (~ 1:10,000 etc) suitable for use at a municipality level.

4.3.3 Gaps in capacity building of basic data, inventory, mapping etc. in large scale

There is no institutional framework for collection and preservation of basic landslide data. Similarly, the inventory maps of landslides are being prepared by different agencies in a scale not generally usable on the ground. The large scale mapping, which is must for landslide studies, is rarely done in the country which is therefore a huge gap to be filled for a meaningful mitigation and management of landslides. Therefore, capacity building of professionals in line department of States / UT's will be carried out for creation of uniform landslide catalogue and mapping.

4.3.4 Gaps in capacity development of professionals i.e. Training of Trainers (ToT)

At present, no Ministry / Department of the Government of India have dedicated project for the training of professionals such as Civil Engineers, Geologist, Geotechnical Engineers, Disaster Managers etc. as trainers for mitigation and management of landslides to reduce risk in collaboration with other national and international agencies by involving new tools and methods. Geological Survey of India (GSI) which is the nodal agency for landslides in the country has been primarily carrying out study and investigation of landslides in the various States and undertaking Landslide Hazard Zonation mapping and few trainings of geologists on landslide investigation and studies only. Formulation and implementation of mitigation projects is invariably left to be carried out by the State governments.

4.3.5 Gaps in identification of target groups for training on landslide DRR

(i) The target groups to be trained are not clearly defined for most of the training programs at state, district and block level.

(ii) In most of the training programs the same heterogeneous group of trainees is imparted training to deal with various stages of disaster management cycle, whereas the involvement, roles and responsibilities of various stakeholders are different during the different phases of disaster management cycle.

(iii) Many Community Based Organizations (CBOs) are left out in the capacity building and training initiatives aimed at DRR.

4.3.6 Gaps in the contents of training programmes on landslide DRR

(i) Most of the training programs on landslides DRR have generalized contents dealing more with the concept, definitions and types of landslides etc.

(ii) Theoretical part on concept of disaster management constitutes a large part of the course content. Fewer contents of practical aspects of landslide DRR do not serve the purpose of training and capacity building programs at the lower level of administrative hierarchy (tehsil, block and village level).

(iii) Case studies indicating effective preparedness, mitigation, response, recovery and rehabilitation pertaining to a landslide event are missing in most of the training programs.

(iv) Local hazard scenario, vulnerability and elements at risk are not included in detail in the contents of most of the training programs.

(v) Site visits of past landslide events are also not a part of the course content in many training programs.

(vi) Course material for various courses at different levels of administrative hierarchy viz state, district, tehsil, is more or less the same without any substantial change in the text of the content. This makes it rather difficult to understand their role in the larger spectrum of landslide risk mitigation.

(vii) Clear guidelines in the form of separate manuals on involvement, role and responsibilities of different stakeholders in landslide DRR are missing.

(viii) Mock drills are generally not a part of the training programs on landslide DRR.

4.3.7 Gaps in capacity building at professional level

After 80's the mushrooming of organizations working on landslide have spread across the country, but the quality of professionals engaged in such studies seems not matching to required level because they have taken the subject as an add-on to their established institutional framework and discipline as part-time and not completely dedicated to this profession.

4.3.8 Gaps in the capacity building initiative at grass root level

(i) Fewer training programs are organized at village and ward level.

(ii) Training programs at the village level are not linked to any financial incentives and the villagers attend these programmes at the cost of their daily wages or farming hours.

(iii) There are virtually no trainings on landslide safe site selection for construction of new houses. Teaching of basic geology of the area differentiating rock types especially the one that are more prone for landslides.

(iv) No pace setter example has been identified till now even after so many years of research which could act as an example for the stakeholders to replicate them for their problems.

(v) Presently, there is no initiative to prepare a catalogue of traditional disaster management practices or the do's and don'ts during disasters including landslides.

(vi) There is a lack of initiative to combine the modern technical knowhow with the coping mechanism of local communities developed by them through experiential learning of generations.

(vii) Educating local women as key stakeholders needs to be promoted, as women and children tend to be victims of hazards, but can also be more effective change-makers in the community.

(viii) Remedial measures using the local slided material for instant temporary stability.

(ix) Educating locals about the landslide dam formation and LLOF (landslide lake outburst flow) and its consequences downstream is another aspect that has not been given due importance so far.

4.3.9 Gaps in coordination among various stakeholders of Landslide Hazard prone areas

Locals are the first and probably the best observers of the slow but progressive landslides in and around the place of their inhabitance. However, it may remain unnoticed in most of the cases due to a lack of awareness about the inherent hazard or due to communication gaps between the vulnerable community and disaster managers at tehsil and or district level.

(i) Implementation of development plans, regulated growth of new habitations, execution of landslide risk reduction programmes and such other activities would move much faster if bridges of understanding are built between teams of specialists, development planners, economists, decision makers and community leaders.

(ii) Lack of proper training, awareness and in many cases, ignorance, non adherence to landuse regulations has encouraged unplanned slope cutting and overloading for commercial gains. The recently enacted slope modification regulations of the Aizawl Municipal Corporation can be a good model for other regulatory bodies in landslide prone areas to follow.

(iii) There is lack of regulations which covers slope modification and also guidance for the safe disposal hill slope cut waste material as well as inherent lack of coordination among various stakeholders in landslide DRR including the government departments, contractors, developers/builders and the community as well.

4.3.10 Gaps in the Presence of Professional Geologists in Municipalities prone to landslides

Even though staff engineers are considered necessary in Municipalities, the position of a staff geologist, geo-morphologist is not present in the Line Department of States such as Municipalities. It is important to create staff positions in Municipalities, PWD's and districts administration with high landslide risks.

4.4 Recommendations

4.4.1 Inclusion of new technology inputs for capacity building and training programs on landslide DRR

(i) Remote Sensing techniques combined with high resolution satellite data on GIS platform, GPS, UAV etc. can be made available and proper training in handling these data should be imparted.

(ii) The Unmanned Aircraft System (UAS) can be used for hazardous site inspection. Specific skill development in handling Unmanned Aircraft System (UAS) for landslide hazard mapping shall be introduced for the scientists and researches of geospatial fraternity for the purpose of precision mapping and better management of landslides.

[**Action**: Ministry of Mines (MoM)/GSI, NIDM, IIRS, NRSC and other expert institutions and stakeholders]

4.4.2 Identification of genuine targets group for training on landslide DRR

(i) Separate target groups should be identified for Specific Skill Development Programmes on landslide DRR e.g. a) Group of civil engineers and geologists for training on structural mitigation of landslides, b) Group of administrators for non-structural mitigation of landslides, c) Group of the Village Disaster Management Teams from landslide prone villages for training on preparedness and response to landslides.

(ii) Modules for DRR trainings for NGOs and CBOs working in the field of preparedness and mitigation, response, recovery, rehabilitation etc. should be developed giving trainees a general specific view and its importance and then training on specific skill development.

[**Action**: Ministry of Mines (MoM)/GSI in collaboration with NIDM and in consultation with NDMA]

4.4.3 Upgradation and simplification of the contents of training programme on landslide DRR

(i) It should be mandatory to include in all

the landslide DRR trainings one or two case studies highlighting landslide disaster management through coordinated efforts of various stakeholders including the affected local community.

(ii) Local hazard scenario, vulnerability, elements at risk should be integral part of any landslide DRR training program in a manner illustrated below:-

a) Landslide DRR training at State level: Landslide hazard scenario, vulnerability and elements at risk in various regions in the districts of the State with some case studies on landslide mitigation and management. The state level committee should be responsible to keep a check on district and village level trainings as well. At times, high level committee in SDMA, having good experience in the disaster management field should be present in order to keep a tab on the level of training and give their input on national level.

[**Action**: State Governments /SDMA's]

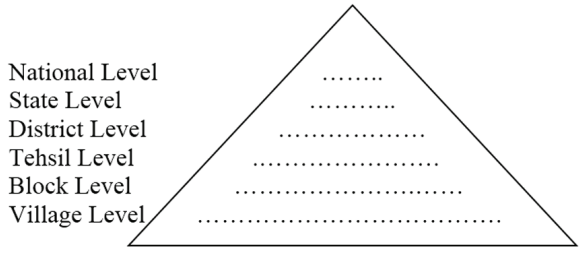

Figure 2. Number of training programmes at various levels

b) Landslide DRR trainings at District level: Landslide hazard scenario, vulnerability and elements at risk in different tehsils and blocks of the district and a general overview of the chronic landslide zones and potential landslides of the district and details of the required mitigation measures. Also it will be beneficial to include landslide database formation with every minute detail which occurred in that district in order to keep a record which can be used by scientists and researchers for study purpose.

[**Action**: State Governments / SDMA's/ DDMA's]

c) Landslide DRR trainings at Village level: Landslide hazard, vulnerability, elements at risk in different hamlets of the village. Identification of landslide safe locations in the proximity of the village for the purpose of construction of temporary or permanent landslide and flash flood safe shelters.

[**Action**: State Governments / SDMA's/ DDMA's]

(iii) Field visits to the sites of major landslide events of the past and or present chronic slide zones/ potential slide zones should be included in all the training programmes on landslide DRR.

[**Action**: State Governments / SDMA's/ DDMA's in consultation with Nodal Ministry / Agency (MoM/GSI)]

4.4.4 Strengthening response framework through capacity building and training of vulnerable communities at grass root level

(i) Landslide disasters are viewed as unmanaged development risks and unresolved problems of the development process. Community Based Disaster Management (CBDM) should lead to a general improvement of the quality of life of the vast majority of the poor people and of the natural environment.

[**Action**: State Governments / SDMA's/ DDMA's]

(ii) Capacity building strategy for DRR at micro level shall include following measures for strengthening 'Disaster Response Framework' at the village level:-

a) Village Disaster Management Teams (VDMTs) should be sensitized about the hazard, vulnerability and elements at risk in their respective village and surroundings. It is very important to train the locals and prepare them better since when the disaster hits, they the first one to get affected.

b) VDMTs should be equipped with solar lights, first aid boxes, ropes and

emergency communication systems such as HAM Radios.

c) Regular training sessions should be conducted for specific skill development of VDMTs in search and rescue and medical first aid in order to ensure the effective and prompt action by them in the event of a disaster.

[**Action**: State Governments / SDMA's/ DDMA's]

(iii) Prioritization of following activities of Village Disaster Management Teams (VDMTs)/ Village Disaster Intervention Teams (VDITs) as suggested by some earlier workers is required as a part of effective Capacity Building & Training Strategy:

a) Bringing forth the awareness with consciousness among community about the hazard, vulnerability and elements at risk, do's and don'ts during and after the disaster by jointly organizing interactive sessions along with the line departments like Medical and Health Department, Public Works Department, Department of Disaster Management, disaster management experts and NGOs etc.

b) Creation of Village Disaster Management Plans (VDMPs) through participatory risk assessment with the participation of VDMTs, locals and students while the government agencies and NGO's can act as facilitators.

[**Action**: State Governments / SDMA's/ DDMA's in coordination with line Departments in the States and other Stakeholders]

(iv) The traditional knowledge accumulated through experiential learning of generations, needs to be documented and this is only possible through interactive sessions, where in the participating village elders may share their experience or impart the knowledge and the youngsters particularly school children can acquire and document it in the form of small projects/ dissertation work etc. The school safety projects aimed at school disaster education trainings to teachers and students.

[**Action**: MHRD, State Governments / SDMA's in coordination with line Departments in the States and other Stakeholders]

4.4.6 Elimination of communication gaps in reading the signs of landslides and for necessary pre-emptive action

(i) In order to enhance the resilience of community to landslide disaster risk, the vulnerable communities of landslide prone locations should be trained through specific skill development program (in landslide DRR) in reading the following indicators of landslides as elaborated below:

a) Subsidence of road, foot/mule track, crop fields, displacement of canals, tilting of fencing pillars, trees, telephone towers and poles etc. Furthermore, a gradual or sudden increase in the amount of tilt is also noticed in some cases.

b) Emergence of large cracks or sudden widening of existing cracks in the upper reaches of hill slope.

c) Emergence of small slide zones (in the vicinity of a large active slide zone) and their head-ward shifting towards the neighboring large active slide zone.

d) Sudden disappearance of some seepage zones and emergence of new springs and seepage zones in their proximity.

[**Action**: State Governments / SDMA's/ DDMA's]

4.4.7 Provisions for financial incentives

Linking village level capacity building and training programmes on landslide DRR to financial incentives is need of the hour. It can be done in the following ways:

(i) Provisions shall be made under MNREGA scheme for undertaking small scale structural mitigation of landslides.

[**Action**: Ministry of Rural Development (MoRD) in consultation with Niti Aayog]

(ii) The village training level programmes on landslide DRR shall have some well-defined tasks in the form of mock drills and simulation exercises (in the course module) to be executed by the trainees in separate categories of (a) Men, (b) women, (c) Children (d) Old aged persons etc. The winners should be given some financial remuneration.

[**Action**: State Governments / SDMA's/ DDMA's]

(iii) Village Disaster Management Team (VDMT) or Village Disaster Intervention Team (VDIT) members should also be given some honorarium after successful completion of the training on landslide DRR.

[**Action**: State Governments / SDMA's/ DDMA's]

(iv) For all ongoing and new development projects involving Landslide risk management, the project construction, and the corrective action for countering the construction related, visible or anticipated slope failures and environmental damage, before, during or after the construction stage, ought to be considered in design as its inseparable parts.

[**Action**: Central Ministries in collaboration with State Governments / SDMA's/DDMA's]

4.5 Implementation Strategy

The multi-faceted aspects of landslide management, especially risk assessment, prevention, mitigation, preparedness and response require an inter disciplinary cross-sectoral and multi-level action strategy to be implemented through education, training and capacity building of all the stakeholders, so as to make them act in an integrated manner towards a convergent holistic approach for mainstreaming landslide risk management.

4.5.1 Implementing Agency: Various agencies can be identified for implementation of the strategy on capacity building and training of stakeholders. Some of these are listed below:

1. National Institute of Disaster Management (NIDM), New Delhi
2. Institutes of Department of Science and Technology, Govt. of India such as Wadia Institute of Himalayan Geology (WIHG), Dehradun
3. Constituent establishment of CSIR such as Central Building Research Institute (CBRI), Roorkee and Central Road Research Institute (CRRI), Delhi
4. Indian Institute of Remote Sensing (IIRS), Dehradun
5. National Remote Sensing Centre (NRSC), Hyderabad
6. Defense Terrain Research Laboratory (DTRL), DRDO, New Delhi
7. Following institutes/centres of the Himalayan States, North-eastern States, Western and Eastern Ghats:
   - (i) Disaster Management Centres under Department of Disaster Management
   - (ii) Disaster Management Cells (DMCs) under Administrative Academies/ Academy of Administration
   - (iii) State Remote Sensing Applications Centres of landslide prone states and any other state Remote Sensing Applications Centre interested in imparting training on landslide DRR
   - (iv) Indian Institute of Technology (IIT's) / National Institute of Technology (NIT's)
   - (v) State Institutes of Rural Development (SIRDs)
   - (vi) Regional Institutes of Rural Development (RIRDs)
   - (vii) Central Government Universities located in landslide affected States
   - (viii) Voluntary commitment by NGOs to the capacity building and training of stakeholders on landslide DRR at grass root level should also be encouraged in a big way. Any other international, national, state, regional or local organization/institution/centre (owned either by government or NGO) having experience of imparting training on landslide DRR.

4.6 Financial Implications:

4.6.1 Centre-State and Public-Private Partnership

Initiatives like this can help in mobilizing financial resources for capacity building and training of stakeholders in landslide DRR. Business houses, business consortiums and companies involved in the developmental infrastructure projects in landslide prone hill regions can be involved through CSR in the initiatives aimed at the capacity building & training on landslide DRR.

4.6.2 Fund provision in budget estimates of BRO & State PWDs

Separate provisions shall be made for landslide mitigation measures in the budget estimates for new roads planned by various departments and agencies of central and the state governments in the landslide prone states and UTs.

Hiring the local workforce for this initiative will not only decrease the possibility of anthropogenically induced landslides but will also help in reducing the economic vulnerability of local labor workforce.

4.6.3 Fund Provision by DoPT for training on landslide DRR

Department of Personnel and Training (DoPT), Government of India can also make some additional provisions for trainings aimed at specific skill development in landslide DRR for the landslide prone states and UTs.

4.7 Monitoring Mechanism

A three tier monitoring mechanism (in synergy with the existing institutional arrangement for disaster management) is proposed for monitoring the progress of capacity building and training of stakeholders.

S.N.	Administrative Unit/Level	Activities	Monitoring Authority
1.	Village, Block & Tehsil	All the Capacity Building and Training programmes on landslide DRR & CCA	District Disaster Management Authority (DDMA)
2.	District and Division	All the Capacity Building and Training programmes on landslide DRR & CCA	State Disaster Management Authority (SDMA)
3.	State, National and International Level (with participation of the country)	All the Capacity Building and Training programmes on landslide DRR & CCA	National Disaster Management Authority (NDMA)

5 Preparation of Mountain Zone Regulations & Policies

5.1 Introduction

The country is vulnerable to one or multiple disasters including landslide and related hazards like cloud burst and flash flood, which are considered to be one of the most dangerous and destructive natural hazards in terms of loss of live and property in Himalaya and Western Ghats. The wide spread property loss during recent landslide and related hazards like cloud burst and flash flood have shown that most of the constructions plans are ill-conceived and do not follow standard norms. The design codes are generally not followed even by the government departments. This has created an alarming situation, where large number of unsafe building stock is added each year to the already huge number of existing unsafe buildings in hostile climate, fragile environment and tectonically active unstable of hilly terrain.

There is no landuse policy in the country at National, State and local level for implementation. The cities of the Himalayas are growing and beginning to turn into the mountains of garbage and plastic, untreated sewage, chronic water shortages, unplanned urban growth and even local air pollution because of vehicles. These towns need to be planned, particularly keeping in mind the rush of summer tourists. Many states have experimented from banning plastics, to taxing tourists to better respond to these issues. But they need support and new thinking on everything on traditional architecture practices, local water management through protection of lakes and different systems of sewage and garbage management. Following points were discussed during formulation of sub-group V strategy document as given under:-

1) Existing regulations and building bye-laws needed to be stringently enforced.
2) There is requirement of implementation of policies by multiple agencies in holistic manner
3) The issues of land loss is landslide affected areas were highlighted and use of bamboo in bio-engineering was emphasized.
4) It was also decided to review the State Town and Country Planning Act was well as the zoning regulations so as to ensure that these are in conformity.

5.2 Identified gaps

Certain issues were very prominent and were identified as gaps such as:-

(1) National Landslide Mitigation Policy (NLMP) which is a must for National Landslide Mitigation Strategy (NLMS) should be common all over the country while NLMS must be developed by the States and be area/problem specific but must reflect the NLMP.

(2) Slope instability management, reflecting the potential for sliding and landslide management, representing the ongoing event/process should be two separate components of NLMS.

(3) The existing bye laws/regulations at local body or state level should be incorporated in the NLMP and NLMS. They should not contradict each other.

(4) NLMP and NLMS should not contradict National Environment Policy and therefore, they should be validated by the MoEF&CC.

(5) Best practices which are used to mitigate landslide at local level and activities which can be held responsible for the landslide hazard should be documented in the NLMP.

(6) Since preventing /preparing for the landslides/slope instability is much easy and cost effective than mitigating/reclaiming the landslide/slope instability. Emphasis must be given to prevention /preparedness in NLMP and NLMS.

(7) Complexity of issues in Darjeeling district due to dual administration. The political imbroglio in the district results in West Bengal Govt and GTA (Gorkha Territorial Administration) being constantly at logger heads with each other. As such, there is dual control over Disaster Management.

(8) Unplanned developmental activities in mountains including huge investments in construction of non-engineered roads in rural areas and lack of drainage which are exacerbating and increasing risk.

(9) Necessity of load bearing tests, hazard zonation, slope and land-use maps to guide urban planners for clearing constructions.

(10) Impact of landslides on rural communities where loss of large areas of farmland has ruined livelihoods and puts a big question mark on food security in the mountains. Compensation for land lost in landslides for farmers needs to be addressed.

(11) Necessity of DDMAs to apply for and utilize disaster mitigation funds.

(12) DDMA to obtain land-use, asset and other useful maps from West Bengal State Remote Sensing Centre.

(13) Paucity of basic data (e.g., rainfall) in mountainous areas and especially in the North East.

(14) Necessity of inducting representations from North Eastern states in the formulation of landslide strategy.

(15) Need for the National Strategy to focus on implementation and enforcement of laws/ regulations and accountability.

(16) Need for better all round coordination between the Panchayats, Line departments, Forest department and Municipal authorities for management of jhoras and drainage outside municipal limits.

(17) State specific landslide mitigation strategies to be formulated to address specific issues of each mountain state.

(18) Urban centers and towns in mountain areas being burdened beyond the carrying capacity by tourism and rural-to-urban migration. Need for satellite towns.

(19) The municipal byelaws must provide for construction activity to be regulated in areas, which fall in hazard zones or areas close to rivers, springs and watersheds of the towns. In many cases these provisions exist in the byelaws, but have not been strictly enforced.

5.3 Review of Work

All the major sub-components of Mountain Zone Regulations and Policies are discussed by the experts are given as under:-

1. Formulation of land-use policies and techno legal regime; all the members felt that there is a need to have strategies for utilization of land and its management for sustainable development of Indian Himalayan Region (IHR) and Western Ghats (WG). It was noticed that the country already has a National Landuse Policy (NLP) which has been updated in 2013. However, in the NLP 2013 there is no specific mention of any landuse policy for IHR and WG. Members of the sub-group mention that every State Government shall prepare State Land Utilization Policy (SLUP) within a period of one year. For the States having total area under mountain zone SLUPs, it is assumed, must have taken all their specific requirements into consideration. However, for the States having partial coverage of mountain zone such as West Bengal there must be a separate mention of hill area land use policy. Then there are the jurisdictional issues of State Government and GTA.

   In the micro-level the Urban Local Bodies (ULBs) of IHR and WG States are either not having local landuse planning or if they have it not being updated. It is resulting into ill-conceived planning, unplanned development and ultimately slope instability.

2. In the section Updation and enforcement of building regulations and bye laws by State Governments/Local bodies, it is observed that almost in every State there is a provision of State Municipal Act. However, the Acts of almost all the IHR and WG states are more focused on other issues than landslide problems. It is noticed that (i) the building regulations and bye laws are not either updated as per the requirement or (ii) they are not having any strong implementation mechanism support.

3. The third section of sub-component is on Review and revision of BIS code/guidelines for landslide management. The following observations have been made by the Sub-Group V:

   I. Master Plan/Development Plan provides a legal framework within which development of an area takes place.

   II. Landuse zoning and development promotion/control regulations serve as legal instruments for planning and executing proposals contained in the plan.

   III. The zoning and development promotion regulations are generally too many, very complex and difficult to comprehend and enforce.

   IV. There is therefore, need to have simplified regulations so that these are adoptable and enforceable within the changing socio-economic and physical development.

   V. Zoning and development promotion regulations include:

   A. Land use classification

   a. For perspective plans

   b. For development plans

   c. For layouts of projects/schemes

   B. Land use zoning regulations

   a. The main purpose of landuse zoning is to provide regulations for development of an area to serve the desired purpose efficiently and to preserve its character.

   b. To promote a healthy and balanced development, it is necessary to apply reasonable limitations on use of lands and buildings – USE ZONES.

   c. Zoning protects residential areas from harmful invasions of other NON-CONFORMING uses.

   C. Development promotion/control regulations

   a. The basic purpose of such regulations is to promote quality of life of people by organizing the appropriate development of land in accordance with the developmental policies and the land use proposals contained therein.

   b. The development promotion regulations deal with designated use zones and use premises.

   c. Development promotion/control regulations are generally provided as part of the development plan under the (urban/special area) planning legislation of the State Government.

   d. These regulations are mainly to specify the quantum of construction, specific location of the structure in various use zones for the activities to be developed/ provided.

National Building Code of India, taking into consideration the Indian Standards & Guidelines for Landslide safety are:-

- IS14458 (Part 1): 1998 Guidelines for retaining wall for hill area; Part 1 Selection of type of wall.
- IS 14458 (Part 2): 1997 Guidelines for retaining wall for hill area; Part 2 Design of retaining/ breast walls.
- IS 14458 (Part 3): 1998 Guidelines for retaining wall for hill area; Part 3 Construction of dry stone walls.
- IS14496 (Part2): 1998 Guidelines for the

preparation of landslide Hazard zonation maps in mountainous terrains; Part 2 Macro Zonation.

Note: The latest version of National Building Code (NBC) shall be followed.

5.4 Proposed Amendment & Regulations

Building regulations considered for study are taken from the latest development plans and building bye-laws available on websites of local governing authorities.

Different documents used in the study are as follows:-

1. Draft Development plan for the Shimla planning area, 2021.
2. Draft Development plan for the Manali Planning area, 2021.
3. Draft Development plan for the Dalhousie Planning area, 2021.
4. Nainital Lake Region Special Area Development Authority Building Regulations.
5. The Sikkim Building Construction (Amendment) Regulations, 2000.
6. Meghalaya Building-Bye Laws, 2011.
7. Building Regulations and Bye-Laws (Kashmir Division), 2010.
8. Mussoorie Dehradun Development Authority Building Construction and Development bye-laws (Amendment), 2003.
9. Town and Country Planning Legislation
   a. Model Town & Country Planning Act 1960
   b. Model Regional and Town Planning and Development Laws 1985
   c. Model Urban and Regional Planning and Development Law (Revised) (Part if UDPFI Guidelines)
10. Land use Zoning, Development Control and Building Regulations
    a. Land use Zoning and Protection of Buildings of Essential Services – Guidelines for Disaster Preventions (document prepared by BMTPC/ADPC)
    b. Review of Current State Legislation on Earthquake Safety in the State of Uttarakhand – a study conducted by BMTPC-ADPC.
    c. Development Control Rules, Master Plan Regulations & Building Bye-laws in the local bodies.
    d. Development Control Regulations of Ahmedabad Urban Development Authority (AUDA)
    e. Development Control Regulations of Mumbai, Pune, Delhi
    f. Draft National Building Code – Part 2 pertaining to administration, and Part 4 pertaining to fire & life safety.
    g. Urban Development Policies and Disaster Risk in Shimla
    h. The Nagaland Building Bye-laws 2012
    i. The Sikkim Building Construction Regulations, 1991
       [As amended by the Sikkim Building Construction (Amendment) Regulations, 2000]
    j. Special Task Force to review Nagaland building byelaws

5.4.1 Proposed Amendment in Town & Country Planning Legislations

Indian hill towns, have numerous problems related to planning and design of buildings, inadequate infrastructure (roads, water supply, sewage, garbage collection and disposal), improper housing/building stock having insufficient strength, unprecedented cutting of vegetation and slopes, pollution, chaos, congestion and degraded living and harm to the natural environment which affects the ecological balance in and around hill towns. Most of these issues/problems are due to inappropriate planning proposals and building regulations enforced in different hill towns. Existing building regulations enforced in Indian hill towns are mostly inspired from Delhi Master Plan(s), which are not appropriate to the context of hill towns, as the geo-environmental and socio-developmental context of Delhi is varied to a greater extent from that of hill towns.

The Town and Country Planning Organization (TCPO), which is an organization of Central

Government to deal with the subject of planning (regional, urban and rural) and developmental policies, formulated a Model Town and Country Planning Act in the year 1960. The Model Act provides as follows:

a. Provisions for preparation of comprehensive Master Plan for urban areas of various states. The states may adopt the Model legislation with suitable modifications for this purpose.

b. To constitute a board to advise and to coordinate in the matter of planning and plan formulation by the Local Planning Authorities in the State.

c. Provisions for implementation and enforcement of the Master Plans and the miscellaneous provisions to achieve planned urban growth of various urban areas in the state.

The above model was revised in 1985 by the Central Town and Country Planning Organisation (TCPO). The revised model regional and town planning and development law has largely been the basis for the enactment of comprehensive urban and regional planning legislation in the States and UT's. The legality of this model has been confirmed by the Ministry of Law. Under this law, planning and plan implementation have been combined together so that a single agency could undertake both these functions. To do this, the planning and development authority to be constituted under the Law has been equipped with full planning and development powers to discharge this task. A revised model for Urban & Regional Planning and Development law was brought out, and guidelines on Urban Development Plan Formulation and Implementation (UDPFI) have been formulated in 1991.

5.4.2 Regulations for Land Use Zoning for Natural Hazard Prone Areas

The regulations for Land Use Zoning for Natural Hazard Prone Areas are to be notified under section:

a. u/s 73(f) of Model Town & Country Planning Act, 1960;

b. u/s 143(f) of Model Regional and Town Planning and Development Law;

c. u/s 181(f) of Model Urban & Regional Planning and Development Law (Revised) of UDPFI

Guidelines as may be applicable in the respective States under the existing provisions of Town & Country Planning Legislation as and when Master Plan/ Development Plan of different cities/ town/ areas are formulated. However, these zoning regulations are to be implemented through the provisions of Development Control Regulations/ Building Bye-Laws, wherever the Master Plan is not in existence or not formulated.

Classification of urban land uses is based upon the requirements of the various plans. For example, a perspective plan, which is a policy document, need not show many details of a specific land use and may only show the main use which could be, say, residential or commercial. In the case of a development plan, which is a comprehensive plan indicating use of each parcel of land, there is a need to show more details of a specific land use. It has to indicate for the land designated as, say, commercial, the further details as to which land is for retail commercial, or for wholesale trade or for godowns. There could be three levels in land use classification shown under:

Level I	For Perspective Plans
Level II	For Development Plans
Level III	For Layouts of Projects/Schemes

5.4.2.1 Land Use Zoning

The main purpose of the land use zoning is to provide regulations for development of a particular area to serve the desired purpose efficiently and to preserve its character. Zoning regulations are legal tools for guiding the use of land and protection of public health, welfare and safety. Such regulations also include provisions for the use of premises/ property and limitations upon shape, size and type of buildings that are constructed or occupy the land. Further, these provide both horizontal as well as vertical use of land.

5.4.2.2 Use Zones

In order to promote a healthy and balanced development, it is necessary to apply reasonable

limitations on use of lands and buildings. For desirable development, the city is divided into a number of 'use zones' such as residential, commercial, industrial recreational, etc. For each zone, specific regulations are provided for and single set of regulations cannot be applied for the whole city.

5.4.2.3 Non-Conforming Use

Zoning protects residential areas from harmful invasions of other uses like industrial use and commercial use. However, it does not prohibit use of lands and buildings that are lawfully established prior to coming into effect of such zoning regulations. If such uses are contrary to regulations in a particular 'use zone' and are not to be allowed, such uses are designated as 'non-conforming uses'.

5.4.2.4 Applicability

a. Areas planned under State Perspective Plan/ Regional Plan/ Master Plan/ Development Plan

- State Perspective Plan/Regional Plan
- Development Plan (Master Plan/Zonal Development Plan)

While formulating Perspective Plan/Regional Plan, Development Plan (Master Plan/Zonal Development Plan) for any notified area, the proposals should indicate natural hazard prone areas with the type and extent of likely hazards.

b. Areas not covered under Master Plan

In such areas where there are no Master Plans or Development Plans, general guidelines and recommendations on natural disaster mitigation should be issued to the various local bodies, Municipalities and Town Area Committees and Panchayats to enable them to take these into consideration while setting up various projects and deciding on construction of buildings etc. Technical help may be required by some of the local bodies in the implementation of the recommendations and for interpretation of the guidelines.

5.4.2.5 Approach for Landuse Zoning

Having identified the hazard prone areas the following alternatives can be adopted for dealing with the disaster risk problems.

a. Leaving the area unprotected: In this case it will be necessary to specify Land Use Zoning for various development purposes as recommended.

b. Using protection methods for the areas as a whole or in the construction of buildings, structures and infrastructure facilities to cater for the hazard intensities likely in the planning area.

c. It will be appropriate to prioritise buildings, structures and infrastructures in terms of their importance from the point of view of impact of damage on the socio-economic structure of the society.

5.4.2.6 Prioritization

In regard to Land Use Zoning, different types of buildings and utility services are grouped under three priorities as indicated below:-

Priority 1. Defence installation, industries, public utilities, life line structures like hospitals, electricity installations, water supply, telephone exchange, aerodromes and railway stations; commercial centres, libraries, other buildings or installations with contents of high economic value.

Priority 2. Public and Semi Public institutions, Government offices, and residential areas.

Priority 3. Parks, play grounds, wood lands, gardens, green belts, and recreational areas.

5.4.2.7 Planning in Hill Areas

In order to ensure environmentally sound development of hill towns, the following restrictions and conditions may be proposed for future activities.

a. An integrated development plan may be prepared taking into consideration environmental and other relevant factors.

b. Water bodies including underground water bodies in water scares areas should be protected.

c. Where cutting of hill slope in an area causes ecological damage and slope instability in adjacent areas, such cuttings shall not be undertaken unless appropriate measures are taken.

d. No construction should be ordinarily undertaken in areas having slope above 30º or areas which fall in landslide hazard zones or areas falling on the spring lines and first order streams.

e. Construction may be permitted in areas with slope between 10^0 to 30^0 or spring recharge areas or old landslide zones with such restrictions as the competent authority may decide.

5.4.2.8 Identification of Open Spaces

Out of the open spaces ear-marked as district parks, neighborhood parks and local parks in the development plan, zonal plans and local plans, should be identified for the use during the emergency to provide shelter and relief caused by a natural hazard. Such pockets should be clearly marked on the city maps.

5.4.2.9 Savings

a. Notwithstanding anything contained in any other regulation for the time being in force, the Regulations for Land Use Zoning for Natural Hazard Prone Areas shall have an over-riding effect for planning and development purposes.

b. In any specific circumstances, if any part of the Regulations has to be relaxed then it will be incumbent on the part of the user to adopt safe guard and protective measures to the satisfaction of the Competent Authority.

5.4.2.10 Additional Provisions

Additional provisions with regard to Land Use Zoning for Natural Hazard Areas are suggested in various existing Model Planning Legislation –

a. Sub-Section 73(f) of Model Town & Country Planning Act, 1960; or

b. Sub-Section 143(f) of Model Regional and Town Planning and Development Law; or

c. Sub-Section 181(f) of Model Urban & Regional Planning and Development Law (Revised) of UDPFI Guidelines

It is recommended that the State Government(s) may be advised to suitably incorporate the above suggested sub-sections in their respective Planning Legislation(s), so that Regulations for Land Use Zoning for Natural Hazard Prone Areas may be notified by the competent authority under the above added legal provisions.

5.5 Recommendations

5.5.1 Policy Level Recommendations

a. Government Orders issued by the various State Governments contain a number of provisions to be followed while sanctioning the building plans by the Development Authority, Special Area Development Authority, Corporation, Municipal Board and also by the concerned government department while selecting the site for construction the building. Due to the lack of technically qualified manpower either with the sanctioning authority implementation is very difficult and could not be followed. The State Governments / Sanctioning authorities should have a panel of reputed and technical personnel including SDMA, who can assist as and when required to the building sanctioning authority.

[**Action**: Central Ministries and State Governments / SDMA's/DDMA's in consultation with Ministry of Mines (MoM)/ GSI and NDMA]

b. Central Government may consider giving suitable incentives for adopting landslide safe construction.

[**Action**: Central Ministries and State Governments / SDMA's/DDMA's in consultation with Ministry of Mines (MoM)/ GSI and NDMA]

c. Necessary amendments in Section 26 of Special Area Development Authority Act 1986, as provided in Section 28 (k) of UP Planning and Development Act, 1973, regarding sealing of building, should be made.

[**Action**: Central Ministries and State Governments / SDMA's/DDMA's in consultation with Ministry of Mines (MoM)/ GSI and NDMA]

d. It is observed that most of the government projects are outside the purview of sanctioning authority. Therefore all such

projects when designed should take care of safety provisions and certified by the concerned architects / engineers.

[**Action**: Central Ministries and State Governments / SDMA's/DDMA's in consultation with Ministry of Mines (MoM)/ GSI and NDMA]

e. At present there are number of Acts/Rules/ Regulations applicable in the states. There should be single legislation to control development and building activity which could be formed taking into consideration present legislative framework and incorporating the suggestions made.

[**Action**: Central Ministries and State Governments / SDMA's/DDMA's in consultation with Ministry of Mines (MoM)/ GSI and NDMA]

f. Government and government agency buildings, which are designed by the Government technical department should follow strictly the provisions suggested for safety against natural hazards.

[**Action**: Central Ministries and State Governments / SDMA's/DDMA's in consultation with Ministry of Mines (MoM)/ GSI and NDMA]

g. Buildings constructed under the Pradhan Mantri Awas Yojana (PMAY) and other Government Schemes should strictly follow the provision of Indian Standards.

[**Action**: Central Ministries and State Governments / SDMA's/DDMA's in consultation with Ministry of Mines (MoM)/ GSI and NDMA]

5.5.2 Technical Level Recommendations

a. As most of the government projects like hospital buildings, schools and others are of standard 'type' design, the provision of structural safety against natural hazards should be reflected in all such project in the drawings, and used/implemented on the site.

[**Action**: Central Ministries and State Governments / SDMA's/DDMA's in consultation with Ministry of Mines (MoM)/ GSI and NDMA]

b. Government departments like PWD/ Rural Engineering Services (RES) should incorporate in their curriculum related to construction of buildings, the requirements of IS4326. Corresponding schedule of rates should also include the detail of additional features which are required to be done as per IS 4326.

[**Action**: State Governments / SDMA's/ DDMA's in consultation with Ministry of Mines (MoM)/GSI, BIS and NDMA]

5.5.3 Community Level Recommendations

a. Standard Building Plans, having provision of safety should be made available at the community level, which may consider standard house design of different types of plots, community halls and other common use buildings.

[**Action**: Central Ministries and State Governments / SDMA's/DDMA's in consultation with Ministry of Mines (MoM)/ GSI and NDMA]

b. There is a need to bring awareness at all levels of society, first of all, a high-level awareness program for decision makers regarding safety against natural hazards.

[**Action**: Central Ministries and State Governments / SDMA's/DDMA's in coordination with Ministry of Mines (MoM)/ GSI and NDMA]

c. Awareness / training program is also required to be systematically arranged for engineers / officials working with local authorities regarding safe site selection, construction, bye-laws, regulations, quality control etc.

[**Action**: Central Ministries and State Governments / SDMA's/DDMA's in consultation with Ministry of Mines (MoM)/ GSI, NDMA and NIDM]

d. To further increase awareness at Community level in rural areas, a combined training of BDOs/ADOs at district level should be arranged. BDOs should be capacitated to further train people at block level.

[**Action**: State Governments / SDMA's/ DDMA's in consultation with Ministry of Mines (MoM)/GSI and NDMA]

6 Stabilization & Mitigation of Landslides & Creation of Special Purpose Vehicle (SPV) for Landslide Management

6.1 Introduction

Landslide affects not only human beings but also destroys nature and affects economy and development of the regions. Therefore, there is an immense need of national project for mitigation of landslides and reconstruction-rehabilitation of affected community. At present, no Ministry / Department of the Government of India have any scheme for landslide risk management in the country. The Geological Survey of India (GSI) under the Ministry of Mines (MoM) who are the Nodal Agency for landslide management in India has not yet undertaken any mitigation measures at site. Their role has remained mainly to Landslide investigations, R&D and advice to States for Landslides management. It is noticed that due to resource crunch, most of the States particularly Hilly States are unable to take up mitigation, rehabilitation and reconstruction measures.

In order to fill-in this gap, this strategy document aims at providing necessary full techno-financial support to landslide prone States, who would submit Detailed Project Reports (DPRs) to project sanctioning agency for taking up site specific landslide mitigation measures. Landslides are site specific in nature and since the vulnerability is different in different locations, the methodology / technology for mitigation of each landslide will be different, involving different activities.

6.2 Identified Gaps

The Geological Survey of India (GSI) alone cannot take the entire load of conducting the geological and geo-technical studies for landslides especially landslide mitigation/treatment that are expected to be taken under the project mode in collaboration with the affected State Govts. Because, GSI is presently having a priority national programme on landslide susceptibility mapping (NLSM) operational throughout the country. The most prominent gaps and challenges identified are as given below:-

i) Scattered pool of expertise and peace meal project mode work by expert institutions.

ii) Strengthening education, research and training in landslide mitigation and management of professionals, State Officials and other stakeholders.

iii) Lack of pace-setting best practices of landslide treatment / mitigation.

iv) Updation of Science-Technology-Innovation based holistic, eco-friendly and sustainable approaches in addressing landslide mitigation and management.

v) Non-coherence of landslide mitigation with the challenges posed by extreme weather events, natural resource management, urbanization, industrialization and constructions that unfortunately remain largely unregulated.

vi) Lack of mainstreaming of landslide mitigation with environmental protection and development planning.

Therefore, it is necessary for creation of Special Purpose Vehicle (SPV) and Centre for Landslide Research Studies and Management (CLRSM) to create a techno-scientific pool of expertise in the country. Necessary geo-technical / geological studies required to prepare the DPR may also be allowed to prepare by suitable and authorized technical concerned Department / consultant group of the State Govt. The design and construction part of the protective structures for landslide mitigation may be undertaken by the concerned

Department of the particular State such as Public Works Department (PWD) and if required they can approach technical expert institution for necessary technical advice. The work of monitoring such endeavour can be entrusted on some expert groups involving Geologists, Geo-morphologist, Civil Engineers, Geotechnical Engineers from NHAI, BRO, GSI, Railway, CRRI, CPWD, Expert PSU's, State Govt etc. The successful and long-term implementation of project needs creation of Special Purpose Vehicle (SPV) with following important objectives: (a) Substantial investments (b) Innovative technique for economical & faster execution (c) Collaborative efforts of all stakeholders at one platform (d) Building up capacity of affected States / UTs.

6.3 Recommendations

6.3.1 Preparation of methodology / SOP for identification of most vulnerable landslide sites in States for mitigation purpose

A state wise database of all critical landslides on various important lines of communications needs to be created at national level. Based on criticality and resources/fund available for mitigation needs to be assigned inter-se priority among critical landslides.

A time-bound national programme for controlling all major landslides should be undertaken, for which:-

(i) A National Task Force of expert / committee of professionals should be constituted to catalogue, study and decide management strategies for all the known problematic landslides in the country in consultation with the State Governments, district administration and the civil society,

(ii) Appropriate agencies, institutions and teams should be identified, shortlisted and mandated to implement the programme in a phased manner,

(iii) Rational criteria to classify an individual landslide as minor, medium or major should be prescribed at the outset for uniform adoption and

(iv) Adequate funding should be provided through national landslide mitigation and management projects or by one-time funding from the Central Government.

The present engineering practice relies on fragmentary approaches involving quick-fix treatments of landslides, which end up in their recurrence, year after year, at the very same locations. Paucity of funds, absence of delivery capacity, and urgency to deal with immediate landslide danger are generally cited as reasons for this continuing practice. The permanent solutions to our major landslide problems may appear at the face value to be capital intensive and even unaffordable, but in the true analysis, the benefits of permanently fixing landslides will far overweigh. Presently, geotechnical engineering practice is sufficiently advanced to blend the short and the long term recommendations in a design package by taking recourse to the well established observational method of design and construction. This method makes use of field observations and their analysis during the process of implementation to alter the design as the work proceeds.

[**Action**: Ministry of Mines (MoM)/GSI in consultation with NDMA and TAC and in coordination with concerned State Governments / SDMA's]

6.3.2 The suitable methodology for planning, engineering and control measures for execution of landslide stabilization work and tools/methods for monitoring, inspection, audit and timely lines for completion of the work.

The major sub-components of above mentioned recommendation are:-

6.3.2.1 Site specific landslide stabilization and mitigation of problematic landslides and reconstruction-rehabilitation of affected community by State Govt's.

a) Preparation of DPRs on the basis of NDMA Template by the States/ Agencies.

The States / Agency will be requested to identify most vulnerable landslide sites in their States, where mitigation measures are immediately required. Mitigation of landslide sites will be done on the basis of

Detailed Project Reports (DPRs) submitted by the concerned States / UTs as per NDMA Template for preparation of DPR for landslide risk mitigation.

b) **DPR's will be scrutinized by the Group of Experts on the basis of Cost-Benefit Analysis (CBA).**

The total cost of the DPR proposal (excluding cost of DPR preparation) submitted by the State Govt. / UTs shall be borne by the Project Sanctioning agency, after getting approval of project by Technical Evaluation Committee (TEC) on the basis of Cost Benefit Analysis (CBA). The other element of overall cost shall also include cost towards TEC meetings, site visits project consultant & support staff and cost of project appraisal.

c) **Monitoring, inspections & audit of mitigation work by Expert Group.**

The successful stabilization and mitigation of landslides will be duly reviewed and evaluated in gap of 2 years. The DPRs drawn by the States may also covers (i) Comprehensive model for landslide management and remedial measure; (ii) Real time monitoring of landslides along with remotely operated real time early warning system (iii) Training and capacity building (iv) Evaluation and validation of different remedial measures and (v) Mechanism for coordination such as workshops etc. between Project Sanctioning agency and interested State Governments to make them suitable for project. Technical Evaluation Committee (TEC) will be formed by Project Sanctioning agency drawing experts on landslides from diverse background.

[**Action**: Ministry of Mines (MoM)/GSI in consultation with NDMA and TAC and in coordination with concerned State Governments / SDMA's]

6.3.3 Creation of Special Purpose Vehicle (SPV) out of expert agencies or scientific institutes who could be entrusted with mitigation of identified critical or most vulnerable landslides.

An expert professionals group should be constituted at the national level to catalogue, study and decide risk mitigation strategy for all the known, problematic landslides in the country in consultation with State governments, district administration and the civil society to recommend permanent fixing of the identified landslide hotspots to be undertaken as a national mission with one time funding by the Central Government.

The successful and long-term implementation of project needs creation of Special Purpose Vehicle (SPV) with following important objectives:-

i) Substantial investments with creation of SPV capable of ground execution

ii) Innovative technique for economical & faster execution.

iii) Collaborative efforts of all stakeholders at one platform.

iv) Building up capacity of affected States / UTs.

v) The Core group to study and execute some critical landslide projects

vi) Building team multidisciplinary team of expert to deal critical landslide

viii) Formulation of concept paper with consultation to all concerned experts

[**Action**: Ministry of Mines (MoM)/GSI in consultation with NDMA and TAC and in coordination with concerned State Governments / SDMA's]

6.3.4 Creation of Centre for Landslide Research Studies and Management (CLRSM)

NDMA Guidelines (2009) on Management of Landslides and Snow Avalanches envisages the creation of national level "Centre for Landslide Research Studies and Management (CLRSM)". After detailed study and wide consultations a concept paper has already been submitted to NDMA on Centre for Landslide Research, Studies and Management (CLRSM) for creation and same is under process with competent authorities and it attached with this report. There is an urgent need to create the Centre on highest priority.

A detail proposal on creation of CLRSM has been prepared by Task Force experts and submitted by

NDMA to the Ministry of Mines (MoM)/Geological Survey of India (GSI) in consultation with MHA for taking up action.

[**Action**: Ministry of Mines (MoM)/GSI in consultation with NDMA and TAC]

6.3.5 Need for Procedure for specialized trainings of professionals/personnel in landslide mitigation and management at national level.

There is an urgent need to devise procedure and well defined mechanism to impart specialized training professional and personnel dealing with landslide mitigation and management. The proposed CLRSM will facilitate and create guidelines, procedure and will impart specialized training to enhance the functioning level of various professional, State Government officials and other stakeholders.

[**Action**: Ministry of Mines (MoM)/GSI in consultation with NDMA and TAC]

Annexure-I

Composition of Task Force

Chairman: Lt. Gen. N. C. Marwah (Retd.), Member, NDMA

Sub-Groups	Sub-Groups
1. Generation of User-Friendly Landslide Hazard Maps Head: Dr. Saibal Ghosh, Director, GSI a) Dr. Aniruddha Uniyal, Head Earth Resource Division, RSAC-UP b) Dr. Pankaj Jaiswal, Director (GHRM), GSI c) Dr. Tapas Ranjan Martha, Scientist-E, NRSC d) Dr. Sunil Dhar, AD, Scientist, DTRL-DRDO	**4. Capacity Building and Training of Stakeholders** Head: Dr. Kishor Kumar, Chief Scientist, CSIR-CRRI a) Dr. Surya Parkash, Associate Professor, NIDM b) Shri Anup Karanth, Senior DRM Specialist, World Bank India c) Dr. Aniruddha Uniyal, Head Earth Resource Division, RSAC-UP d) Shri Hari Kumar, Geo-Hazard Society e) Shri Prateek Chaturvedi, Scientist-D, DTRL-DRDO
2.Development of Landslide Monitoring and Early Warning System Head: Dr. P.K. Champati Ray, Head Geoscience, IIRS-ISRO, Dehradun a) Dr. P. N. Joglekar, Scientist-E (Retd.), DTRL-DRDO b) Dr. Vikram Gupta, Scientist-E, WIHG, Dehradun c) Prof. Someshwar Das, Rajasthan University d) Dr. D. P. Kanungo, Principal Scientist, CSIR-CBRI, Roorkee e) Dr. Pankaj Jaiswal, Director (GHRM), GSI f) Dr. Maneesha V. Ramesh Director, Amrita University, Kerala	**5. Preparation of Mountain Zone Regulations & Policies** Head: Prof. R. K. Pande, Kumaun University, Nainital a) Dr. Tapas Ranjan Martha, Scientist-E, NRSC b) Prof. Amita Singh, Chairperson, Centre for Law & Governance & SCDR, JNU c) Shri Praful Rao, President, Save The Hills, Kalimpong d) Shri Rajendra Desai, Joint Director, NCPDP, Ahemadabad, Gujarat e) Dr. Mahesh Gaur, Senior Scientist, ICAR-CAZRI, Jodhpur f) Maj. R. K. Joshi, BRO
3. Awareness Programmes Head: Prof. R. B. Singh, Delhi University a) Prof. Mehtab Singh, MD Univ., Rohtak b) Shri Sarbjit Singh Sahota, UNICEF c) Dr. Subrat Sharma, Scientist-D, GBIHED, Almora d) Dr. Digvijoy Phukan, Mahatma Gandhi University, Bihar	**6. Stabilization and Mitigation of Landslides and Creation of Special Purpose Vehicle (SPV) for Landslide Management** Head: Dr. S. S. Porwal, ADG (Retd.), BRO a) Dr. P. C. Nawani, Consulting Engineering Geologist, Gurugram b) Shri T. S. Routela, AGM (Design), THDC, Rishikesh c) Prof. K. S. Rao, Civil Engineering Deptt., IIT Delhi

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