Training Module on COMPREHENSIVE LANDSLIDES RISK MANAGEMENT
About the Module

This Training Module on COMPREHENSIVE LANDSLIDES RISK MANAGEMENT is designed to provide a comprehensive understanding of landslide risk management. It covers various aspects including causes, prediction methods, mitigation strategies, and case studies from around the world. The module aims to equip learners with the knowledge and skills necessary to manage landslide risks effectively in their respective regions.

About the Author

[Photo of the author]

[Name and credentials]

Training Programme on COMPREHENSIVE LANDSLIDES RISK MANAGEMENT

[Logos and contact information]

NATIONAL INSTITUTE OF DISASTER MANAGEMENT
Ministry of Home Affairs, Government of India
Training Module on
COMPREHENSIVE LANDSLIDES RISK MANAGEMENT

Impacts of Landslides on Society & Environment

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Foreword

The module on “Comprehensive Landslides Risk Management” is developed for a five day training course focusing on imparting basic and requisite knowledge / skills needed by different stakeholders at various levels in the field of Landslide Management.

The module has been divided into sub-modules, each targeting specific learning units to enable certain learning events through well-designed course sessions with the support of a good trainer in the particular field.

The module has been prepared by Dr. Surya Parkash, Associate Professor, NIDM, based on his experience gained from more than 25 training programmes on landslides, all over the country over the past five years. In addition, inputs for preparation of the training module have also been provided by different eological Survey of India (GSI), Border Roads Organization (BRO), Central Road Research Institute (CRRI), Advanced Technical Engineering Services (ATES), Central Building Research Institute (CBRI), Defence Terrain Research Laboratory (DTRL), Snow and Avalanches Studies Establishment (SASE), Wadia Institute of Himalayan Geology (WIHG) and NGOs like Save The Hills, Community Based Disaster Risk Management Society (CBDRMS) and Sphere India. The module has been designed with multi-hazards risk management approach and briefly discusses all types of vulnerabilities for all stakeholders in an integrated holistic manner.

NIDM acknowledges the valuable support from all resource persons and institutes, especially GSI, BRO, ATES and CRRI for providing technical inputs on the module and reviewing the same at various stages of preparation and publication. This training module is developed for use in different training Institutions/centres for capacity in enhancement in the field of Landslides Risk Management.

(Satendra, IFS)
Executive Director,
National Institute of Disaster Management
New Delhi, India
Preface

The Malpa landslide tragedy in August 1998 that killed more than 200 persons on trek to Kailash Mansarovar brought the attention of the Central Government to the problem of landslides. Department of Science & Technology constituted 3 national level task forces to look into different aspects of landslide problems. After the enactment of disaster management act in 2005, National Disaster Management Authority was established under the chairmanship of Hon’ble Prime Minister. The Authority issued national guidelines for management of different types of disasters including landslides and avalanches. The author had assisted NDMA as part of the Core Group and Drafting Committee for the Landslide Guidelines at the national level. He is presently involved with NDMA as part of the National Task Force on Landslides Management and Working Committee of Experts on Landslides.

National Institute of Disaster Management (NIDM), New Delhi has been mandated by the DM Act 2005 to organize training programmes, seminars, workshops and conferences on disaster management including the field of landslides and other mass movements. The experiences gained by the author from the above-said activities have been gathered and used to compile this module for enhancing the knowledge and information related to landslides and disaster management among the different stakeholders.

NIDM has been recently recognized as World Centre of Excellence on Landslide Disaster Reduction (WCoE-LDR) by the Global Promotion Committee of the International Consortium on Landslides (ICL) and International Programme on Landslides by International Strategy for Disaster Reduction (IPL-ISDR), for its contributions in the field of training and capacity development for landslide risk reduction. The author, who in Leader of the WCoE-LDR at NIDM, has also been made Coordinator for the ICL’s Thematic Network on Landslide Risk Management and approved as Project Leader for IPL-172 project on “Training, Documentation and Capacity Development for Landslides Risk Management” under the International Programme on Landslides. He is presently engaged in developing teaching tools for landslide risk reduction with ICL as one of the expert members.
It is hoped that the module will provide an insight to the trainees in the basic understanding about landslides and measures required for reducing the risks at different levels. The trainees are encouraged to interact with field experts and resources persons in this field to prepare themselves better for landslides risk reduction.

(Surya Parkash)
Author
Acknowledgement

At the outset, I would like to express sincere thanks to Dr. Satendra, Executive Director, National Institute of Disaster Management, New Delhi for his kind encouragement for writing this module. I would like to place on record the significant contributions made by different resource persons in compiling the information, database and maps related to landslides in the country. I am particularly thankful to Dr. R.K. Bhandari, Prof. Yudhbir, Dr. Y.P. Sharda, Dr. R.N. Ghosh, Shri M. Raju, Shri Joyesh Bagchi, Shri Sanjiv Sharma, Dr. P.C. Nawani, Shri U.S. Rawat, Dr. R.K. Avasthy, Dr. Saiibal Ghosh, Dr. Pankaj Jaiswal, Shri P.P. Srivastava, Shri Ishwar Singh Duhan, Shri Jog Singh Bhatia, Dr. Tapas Martha, Shri Yadvendra Pandey, Shri Om Prakash Sahu etc. for their fruitful discussions and contributions in preparing the manuscript of this module. I am grateful to the reviewers Dr. V.M. Sharma, Director AIMIL Ltd. and Shri Sanjiv Sharma, Director, LHIM & EPE, Geological Survey of India, for the useful comments on the draft of this Module has helped us improve the quality and standard of its content.

I am sincerely thankful to the international experts like Prof. Kyoji Sasssa, Executive Director, International Consortium on Landslides, Dr. Peter Bobrowsky from Canada, Ms. Lynn Highland from USGS, Prof. Dwikorita Karnawati and Dr. Faisal Fathani from Indonesia, Prof. Alexander Strom from Russia, Dr. S.H. Tabatabei from Iran, Dr. He Bin and Dr. Hiroshi Fukuoka from Japan and so on, who have encouraged me in undertaking challenging tasks related to landslides risk reduction.

I am happy to acknowledge the support and cooperation from my colleagues and supporting staff at NIDM, without which it would not have been possible for the document to be completed. I would like to place on record my thanks to Dr. Chandan Ghosh, Professor and Head, Geohazards Risk Management Division, NIDM and Dr. Ritu Raj for extending necessary help in preparing the module. I would also like to express my sincere gratitude to faculty members and staff of disaster management centres in the different states in the country who have helped in various manners by sharing their experiences, resources, database etc. and made valuable contributions to this effort. Particular thanks are due to Dr. Om Prakash, Shri J.C. Dhondiyyal, Shri Ashok Kumar Sharma, Dr. Hovithal Sothu, Dr. Lal Rokima, Dr. R. Dharmaraju and so on.

Last but not the least, I would like to thank my wife Reeta and my daughter Rasika, without whose consistent moral and logistic support, I would not have been able to give due attention and time to this work. I am indebted for their tolerance to bear with me when I was busy with work related to the module and could not give due attention and care to them.

Finally, I am grateful to the Almighty God without whose grace and kindness, I would not have been capable to carry this task successfully.

(Surya Parkash)
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Author
Module at a Glance

- **Name:** Training Module on Comprehensive Landslides Risk Management
- **Developed by:** Dr. Surya Parkash, Associate Professor, National Institute of Disaster Management (NIDM), New Delhi
- **Technical Support:** Geological Survey of India (GSI), Border Roads Organization (BRO) Central Road Research Institute (CRRI), Advanced Technical Engineering Services (ATES), Central Building Research Institute (CBRI), Snow and Avalanches Studies Establishment (SASE), Wadia Institute of Himalayan Geology (WIHG), Community Based Disaster Risk Management society (CBDRMS)
- **Total Number of sub-modules:** 14
- **Target Audience:** Stakeholders in various sectors at different levels, particularly geologists, engineers (civil, mining and hydel), administrators, planners, NGOs, civil defence, environment agencies etc.
- **Training programme on the basis of this module requires:**
  - Duration of Training: 5 working days (~38-40 working hours)
  - Number of Trainers: 2 or more
  - Training Hall with movable chairs and tables
  - Training Materials as mentioned inside
- **Total Pages:** 278 (excluding annexures/handouts)
- **Photo Courtesy:** Dr. Surya Parkash, NIDM
- **Maps:** Dr. Surya Parkash, NIDM
Who Shall Use This Module

This module shall be used by a trainer involved in conducting courses on landslides risk management. The following individuals / organizations are the potential users of this module.

- Geologists, Civil/Mining/Hydel Engineers, Field Professionals, Architects/Planners, Developers, Environmentalists (in Hilly Terrains)
- NDMA, SDMA, DDMAs. Geological Survey of India, State Departments of Geology and Mines, Academicians, Researchers and Professionals working on landslides
- Disaster Management Centres at State ATIs & SIRDs
- NGOs, CBOs, SHGs, Social Volunteers, Public Representatives
- NDRF, SDRF, QRTs, RRFs, paramilitary and military
- Administration, Local Bodies like Municipality and Panchayats
- NSS, NYKS, NCC, Scouts and Guides, Home Gaurds, civil defense and Fire Fighters
- Field Agencies like Border Roads, PWD, NHAI, PGCL, NHPC, THDC, NTPC, Irrigation and Flood Control etc.
- Stakeholders in Insurance, Finance, Planning, Policy, Development and Legal Sectors

How to Use this Module

The training design brief will provide users the objectives of the course, target audience, structure, training methodologies and resource materials etc.

The chapters on pre and post training assessment will guide on how to carry out the evaluation and impact assessment of the training course along with a set of questionnaires and necessary instructions. The actual training sessions will start with the sub-modules provided in the contents. However, elaborate instruction and guidelines are given for the session in every sub-module.

Trainer’s Guide

The Trainer/Facilitator/Course Director may find the following tips useful for smooth conduct of the training.
General

- In the inauguration / introduction session, trainees should be asked to put their mobiles / cell phones on silent mode and to attend the urgent calls only, that too outside the training hall during the sessions.
- Participants list with names, addresses, contact numbers, email IDs etc. should be circulated for verification by the trainees for necessary corrections.
- All training materials and equipment should be kept ready and re-checked before the training.
- Clear information about lunch hours and tea breaks should be given to trainees to avert any delay. They should be informed about exact time of start of sessions and next day plans.
- Care should be taken for proper logistic arrangements for the trainees to make their stay during the training, comfortable.

Training Specific

Following aspects should be taken care of.

- Each day shall start with a recapitulation session of about 15 minutes except the first day. At the end of each day, summary of the day's proceedings shall be shared by the participants for 10 minutes after the last session.
- Group composition shall change for every activity/exercise through different methods.
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<tr>
<td>ATES</td>
<td>Advanced Technical Engineering Services</td>
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<tr>
<td>ATI</td>
<td>Administrative Training Institute</td>
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<tr>
<td>BIS</td>
<td>Bureau of Indian Standards</td>
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<tr>
<td>BRO</td>
<td>Border Roads Organization</td>
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<tr>
<td>CBDP</td>
<td>Community Based Disaster Planning</td>
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<tr>
<td>CBLRM</td>
<td>Community Based Landslides Risk Management</td>
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<tr>
<td>CBDRM</td>
<td>Community Based Disaster Risk Management</td>
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<tr>
<td>CBO</td>
<td>Community Based Organizations</td>
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<tr>
<td>CBRI</td>
<td>Central Building Research Institute</td>
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<tr>
<td>CLRBM</td>
<td>Comprehensive Landslides Risk Management</td>
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<tr>
<td>CRED</td>
<td>Centre for Research on Epidemiology of Disasters</td>
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<tr>
<td>CRF</td>
<td>Calamity Relief Fund</td>
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<tr>
<td>CRRI</td>
<td>Central Roads Research Institute</td>
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<tr>
<td>DDMA</td>
<td>District Disaster Management Authority</td>
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<tr>
<td>DGBR</td>
<td>Director General Border Roads</td>
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<tr>
<td>DGCD</td>
<td>Director General civil Defence</td>
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<tr>
<td>DGM</td>
<td>Department of Geology and Mines</td>
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<tr>
<td>DMA</td>
<td>Disaster Management Act</td>
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<tr>
<td>DMMG</td>
<td>Department of Mines, Minerals and Geology</td>
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<tr>
<td>DoS</td>
<td>Department of Space</td>
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<tr>
<td>DST</td>
<td>Department of Science &amp; Technology</td>
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<tr>
<td>ESF</td>
<td>Emergency Support Function</td>
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<tr>
<td>GSI</td>
<td>Geological Survey of India</td>
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<tr>
<td>GFDRR</td>
<td>Global Facility for Disaster Reduction and Recovery</td>
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<tr>
<td>HVCR</td>
<td>Hazard, Vulnerability, Capacity and Risk</td>
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<tr>
<td>ICL</td>
<td>International Consortium on Landslides</td>
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<tr>
<td>ILC</td>
<td>International Landslide Centre</td>
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<tr>
<td>IMD</td>
<td>Indian Meteorology Department</td>
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<tr>
<td>IIRS</td>
<td>Indian Institute of Remote Sensing</td>
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<tr>
<td>IPL</td>
<td>International Programme on Landslides</td>
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<tr>
<td>ISDR</td>
<td>International Strategy for Disaster Reduction</td>
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<tr>
<td>ISRO</td>
<td>Indian Space Research Organization</td>
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<tr>
<td>ITBP</td>
<td>Indo Tibetan Border Police</td>
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<tr>
<td>LHZ</td>
<td>Landslides Hazard Zonation</td>
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<tr>
<td>LMP</td>
<td>Landslides Management Plan</td>
<td></td>
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<tr>
<td>LRM</td>
<td>Landslides Risk Management</td>
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<tr>
<td>LSN</td>
<td>Landslides Schools Network</td>
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<tr>
<td>LSZ</td>
<td>Landslides Susceptibility Zonation</td>
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# Abbreviations / Acronyms Used

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<td>MHA</td>
<td>Ministry of Home Affairs</td>
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<tr>
<td>MoM</td>
<td>Ministry of Mines</td>
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<tr>
<td>MoES</td>
<td>Ministry of Earth Sciences</td>
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<tr>
<td>NCCF</td>
<td>National Calamity Contingent Fund</td>
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<tr>
<td>NDMA</td>
<td>National Disaster Management Authority</td>
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<tr>
<td>NDMRC</td>
<td>National Disaster Mitigation Resource Centre</td>
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<tr>
<td>NDRF</td>
<td>National Disaster Response Force</td>
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<tr>
<td>NGO</td>
<td>Non Governmental Organization</td>
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<td>NHAI</td>
<td>National Highways Authority of India</td>
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<td>NHPC</td>
<td>National Hydro Power Corporation</td>
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<tr>
<td>NIDM</td>
<td>National Institute of Disaster Management</td>
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<tr>
<td>NTPC</td>
<td>National Thermal Power Corporation</td>
</tr>
<tr>
<td>NRSC</td>
<td>National Remote Sensing Centre</td>
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<tr>
<td>PGCL</td>
<td>Power Grid Corporation (I) Limited</td>
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<tr>
<td>PWD</td>
<td>Public Works Department</td>
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<tr>
<td>QRT</td>
<td>Quick Response Team</td>
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<tr>
<td>SASE</td>
<td>Snow and Avalanches Studies Establishment</td>
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<tr>
<td>SDMA</td>
<td>State Disaster Management Authority</td>
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<tr>
<td>SDRF</td>
<td>State Disaster Response Fund</td>
</tr>
<tr>
<td>SDRF</td>
<td>State Disaster Response Force</td>
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<tr>
<td>SOP</td>
<td>Standard Operating Procedures</td>
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<tr>
<td>THDC</td>
<td>Tehri Hydro Development Corporation</td>
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<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
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<tr>
<td>UNESCO</td>
<td>United Nations Educational Scientific and Cultural Organisation</td>
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<tr>
<td>UNHCR</td>
<td>United Nations High Commission for Refugees</td>
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<tr>
<td>UNICEF</td>
<td>United Nations Children’s Fund</td>
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<tr>
<td>U.N. OCHA</td>
<td>UN Office for Coordination of Humanitarian Affairs</td>
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<tr>
<td>UNDAC</td>
<td>United Nations Disaster Assessment and Coordination</td>
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<tr>
<td>UNITAR</td>
<td>United Nations Institute for Training and Research</td>
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<tr>
<td>UNU</td>
<td>United Nations University</td>
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<tr>
<td>USD</td>
<td>United States Dollars</td>
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<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
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<td>UT</td>
<td>Union Territories</td>
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<td>VOs</td>
<td>Voluntary Organizations</td>
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<tr>
<td>WBI</td>
<td>World Bank Institute</td>
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<td>WIHG</td>
<td>Wadia Institute of Himalayan Geology</td>
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Glossary / Terminology related to Landslides

Acceptable Risk - A risk for which we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

Cloud Burst: Clouds are formed when water vapors reach a height where temperature is low. Water vapors condense to form small water droplets. When nucleation of such clouds takes place, water droplets grow in size to form raindrops, depending on the thickness of clouds and low temperature, the rain is light or heavy. In case of cloud bursts, cyclonic winds virtually compress the clouds and forced nucleation amounting to sudden precipitation takes place where all the water from the clouds is poured out. This is called cloud burst.

Sudden rainfall with great velocity is called a cloud burst. It results from the condensation of stratus clouds. It does not last very long. Heavy rains on the other hand are caused by nimbus clouds which are black in color and suspended at a lower height.

Controlling (Perpetuating) Factors which dictate the condition of movement as it takes place; i.e. factors which control the form, rate and duration of movement.

Hazard - A condition with the potential for causing an undesirable consequence. Alternatively, the hazard is the probability a particular landslide occurs within a given time and space.

Individual Risk - The risk of fatality and/or injury to any identifiable (named) individual who lives within the zone exposed to the landslide, or who follows a particular pattern of life that might subject him/her to consequences of the landslide.

Landslides are simply defined as down slope movement of rock, debris and/or earth under the influence of gravity. This sudden movement of material causes extensive damage to life, economy and environment. Landslide is the most common and universally accepted collective term for most slope movements of the mass movement type. The term has sometimes been considered unsuitable as the active part of the word denotes sliding.

Mass Movement is outward or downward gravitational movement of earth material without the aid of running water as a transporting agent. It does not deny the importance of water in either its solid or liquid state as a destabilising factor nor does it excludes subsidence and other movements on flat ground.
Mass Wasting is a broader term commonly used in conjunction with the erosion cycle to refer to the mass reduction of the interfluves as opposed to the degradation by streams. In effect it must include the action of all non-linear erosional processes working on the slopes between streams.

Preparatory Factors which dispose the slope to movement; i.e. the factors which make the slope susceptible to movement without actually initiating it and thereby tending to place the slope in a marginally stable state.

Risk - A measure of the probability and severity of an adverse effect to individuals or populations, property or the environment.

Risk Management - The complete process of risk assessment and risk control.

Slope Failure refers to the process of rupture or shearing in materials rather than to a particular ground feature. Terzaghi (1950) advocated this term for slope movements on engineered slopes.

Slope Instability refers to the predisposition of a slope to mass movement. The condition may be recognised by analysis of stress within the slope, by various slope characteristics or by analysis of historical records of slope development.

Slope Movements restricts to mass movements on slopes.

Societal Risk - The risk of multiple injuries or deaths to society whole: one where society would have to carry the burden of a landslide accident causing a number of deaths, injuries, financial, environmental and other losses.

Stability Factors - All forces determining stability are controlled or influenced by identifiable phenomena are referred as Stability factors. When these operate to induce instability, they are called destabilising or causative factors. e.g. climate, slope strength, vegetation etc. Indeed there are many components of the slope system which can change independently to destabilise the slope but the significance of any change is dependent on the aggregated effect of all the components. An examination of the temporal variability of factors identifies some as being passive (slow or gradually changing) e.g weathering, and transient or active (fast changing).

Triggering Factors which initiate movement; i.e those factors which shift the slope from a marg

Tolerable Risk - A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible.
CONTEXT
Landslides occur in hills / mountains in response to a wide variety of terrain conditions and triggering processes like heavy rainstorms, cloudbursts, earthquakes, floods and unsafe developmental activities. As per an assessment, more than 5000 people are buried alive under landslides and economic losses of >4 bn USD occur every year, globally (ICL, 2010). Continent-wise, Asia suffers the maximum damages / losses due to landslides in general and the south Asian nations, in particular, are the worst sufferers. Further, among south Asian countries, India is one of the most affected by landslides.

In our country, nearly 15% of its territory is prone to various degrees of landslide hazard (GSI, 2001), frequently affecting the human life, livelihood, livestock, living places, structures, infrastructure, and natural resources in a big way. In addition to direct and indirect losses, landslides cause significant environmental damages, societal disruption and strategic concern. Landslides are spread over 22 states and 2 Union Territories including Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Arunachal, Assam, Meghalaya, Mizoram, Manipur, Nagaland, Sikkim, Tripura, Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Goa, Maharashtra, Madhya Pradesh, Chhatisgarh, Andaman & Nicobar Islands and Puducherry (NDMA Guidelines, 2009). The most sensitive areas are the Himalayan belt, the Nilgiris, the Western and Eastern Ghats. Landslides constitute a serious hazard that causes substantial human and financial losses in the country. It is estimated that annually on an average about 300 human lives are lost and approximately Rs.300 Crores are lost every year. Bansal and Mathur (1976) reported that annually Rs.350 million are lost due to failure of transport and communication caused by the landslides. Bartarya and Valdiya, 1989 estimated that almost 50% of the landslides occur along the roads. Valdiya, (1987) reported that the incidences of landslides increase by 25 to 345 times due to road construction activities whereas Gupta (1990) estimated that each kilometer of road in hills require displacement of 40 to 80 thousand cubic meter debris.

Landslides can happen not only in isolation but also along with or as a consequence of other disasters like earthquakes, floods, cyclones, lightning, cloudburst, forest fires, dam / lake bursts etc. In such cases, landslide losses are normally included within the primary disaster and hence, are not dealt separately. Thus, most of the reported estimates on landslides losses are found to be quite lower than the actual impacts of landslides on the society as a whole.
With growing population, urbanization and human interventions in terms of developmental activities over unstable slopes, landslides pose increasing risk to human lives, buildings, structures, infra-structures and environment. Changing climatic conditions manifested in the form of global warming, glacial melting, erratic and uneven rains, extreme temperature conditions etc. are also extending these risks to even unexpected areas. Large scale deforestation along with faulty management have led to increased vulnerability to landslides in many regions of the country. Human activities relating to expansion on unsafe locations, unscientific mining, unsafe construction of roads, dams and river training works ignoring natural features contribute to increased intensity of landslides. The absence of large scale landslide hazard maps leads to people being caught unaware especially when the first time landslides strike. This could have been avoided if large scale landslide hazard maps were available and people made aware about the potential hazards.

As a single landslide usually affects limited area and people, damage resulting from landslide hazards are not recognized as a problem of national importance and are not addressed on a national basis. The absence of coordinated national approach to mitigating the detrimental effects of landslides result in a reduced ability of the states and local government agencies to apply the important lessons learnt, often at enhanced expense.

As a result, the need for a national strategy was strongly felt and worked upon by the National Disaster Management Authority through National Disaster Policy and Guidelines on Management of Landslides and Avalanches. Being cognizant of the diversity of issues associated with national landslide problem that arise from both regional considerations and considerable variations in the institutional capability and responsibility at regional and local levels, inputs from a wide variety of stakeholders are essential. Hence, strengthening the process of landslide assessment, investigation, mapping and management is sure to have far reaching effects in reducing landslide losses.

The aim of this training programme is to work in the following directions to make the hilly terrains and coastal areas free of landslide disasters.

- To promote the use of landslide risk analysis techniques to guide loss reduction efforts at the state and local levels.
- To play a vital role in evaluating methods, setting standards, and advancing procedures and guidelines for landslide hazard maps and assessments.
- To provide tools for landslide hazards mitigation and promote basic research on monitoring techniques and on aspects of landslide process mechanics.
To impart education, training and awareness of landslide hazards and mitigation options to decision makers, professionals, and the general public.

To integrate and mainstream landslide risk management with development and climate change in a multi-hazard perspective involving interdisciplinary cross-sectoral partnership approach

To produce implementation and management plans that will provide the practical basis for an effective national strategy that can be applied at local levels.

To support advocacy, policy, guidelines and plans for landslides risk management at different levels among various stakeholders

To develop workable partnerships with states, district and local level governments and non-governmental organizations as well as professional and other stakeholders.

Aim of the Course

To enhance knowledge and skills related to landslides risk management of a multi-stakeholder target group which is expected to play an important role in reducing landslide incidences and impacts through various kinds of activities involving social, technical, legal, financial, environmental, administrative and other relevant issues, aspects and dimensions at different levels/scales.

Course Objectives

At the end of the training program, the participants will be able to

- Define the terms/concepts in landslides risk management and become aware of basic information about landslides
- Describe landslide scenario and mitigation strategy with multi-hazard perspective
- Characterize/identify landslide indicators/precursors and relate factors affecting landslide occurrence and its extents
- Identify the needs, gaps and strategies in landslide databases, inventory & mapping
- Understand the Mechanism for Landslide Hazards, Vulnerability and Risk Assessment, Zonation, Prioritization and Communication for Landslide Risk Reduction
Context

- Learn options for minimizing landslides risks - avoidance, prevention, mitigation (including structural and non-structural measures), preparedness, and response to the disaster
- Assess landslides damages and losses in a systematic way
- Inform about planning, policy and guidelines on landslide risk management as well as roles/responsibilities/SOPs to stakeholders
- Understand cross-sectoral issues like administrative, technical, legal, financial, social etc.
- Enlist and use Indian Standards and Codes related to landslides
- Discuss about the possible applications of technology, local resources/skills, and traditional wisdom in landslides management - Community Based Landslides Risk Management
- Demonstrate through an exercise the process of landslide risk management
- Carry out mock drills for public safety against landslides
- Integrate and mainstream landslide risk management with development and climate change in a multi-hazard perspective with interdisciplinary cross-sectoral partnership approach
- Provide a forum for networking, linkage and coordination among different stakeholders for exchange of ideas, information, knowledge, experiences and resources on landslides risk management

Target Group

The target group for this programme would be senior officers from departments of Revenue, Disaster Management, Geology and Mines, Geological Survey of India, Town Planning, Public Works Department, Border Roads Organization, Irrigation and Flood Control, Rural and Urban Development, Hydropower Sector, Building and Housing Department, State and District Development Authorities, NDRF, Police and Civil Defence, Fire Services, Environment & Forest, Roads and Bridges, Watershed Management, State Science and Technology Council, State Remote Sensing Application Centres, Professional, Research, Academic and Community organizations/Public Representatives etc.

The participants are expected to have varied responsibilities, academic backgrounds & experience. But all of them are required to be equipped with minimal level of knowledge, skills, information and experience related to landslides for doing their tasks in their organizations effectively. They are
expected to deal with disaster management during planning and implementation of developmental activities. The programme is intended to provide a comprehensive knowledge and skills in the field of landslide risk management to these participants.

**Assumptions about Trainees**

It is assumed that the age of trainees varies as they are associated with different sectors. The academic qualifications and level of degrees will also be dissimilar. They may or may not have experience / exposure to disasters prior to the training.

**Why This Training?**

Lack of adequate knowledge, skills and information about landslide disasters have aggravated the losses and prolonged the recovery process. Informed, skilled and trained human resources can play a significant role in landslides risk management and loss reduction. The training aims to fill this gap in a proactive mode by imparting skills, knowledge and information related to landslides management.

**Training Needs**

An interaction with the various concerned organizations over the years has made us believe that landslides incidences and impacts are rising due to lack of adequate number of trained human resources with these organizations besides that fact that affected communities are also unaware, uninformed, unprepared and unequipped. Different stakeholders as well as the affected communities need to be sensitized, aware, informed, prepared and made capable to assess the potential / impending landslides risks, minimize them and gear themselves up against the remnant risk.

**Relevance of Objectives to Training Needs**

The objectives of the training programme are so formulated to cater to the training needs of the different stakeholders for carrying out their tasks more effectively and efficiently in order to reduce landslides risks and manage their impacts on life, economy and environment.

**Time Constraint**

There will be time constraint for holding training course due to the fact that most of landslides happen during monsoon periods and the concerned officials would be busy in managing them. Hence, relevant participants shall be available
only in pre and post monsoon seasons. Thus, timings for the training should preferably be fixed in pre and post monsoon period to enable to attend the training without stress of the field work.

**Trainers**

Senior officers from GSI, BRO and faculty members of NIDM, ATIs, research and academic institutions who have expertise in different aspects of landslide risk management

**Logistics**

Boarding and lodging arrangements for 20-25 trainees / participants.

**Number of trainees / participants**

20 to 25 trainees / participants belonging to various departments / agencies

**Venue(s) for Training**

NIDM, State ATIs and GSI /DMMG training centres

**Entry Behavior**

Geologists, Engineers (civil, mining, irrigation) and concerned field level officers involved in landslide studies and management. Field officers preferably with academic background of geology/ geophysics/ geotechnical engineering/ mining engineering/highway engineering/ irrigation/watershed management/ remote sensing. People with and experience / involvement in landslide risk management will be given preference.

**Content defined in relation to objectives**

- Terms and Concepts in Landslides Risk Management
- Landslide definitions, types, causes, factors, impacts
- Landslide Database, Inventory, and Zonation
- Institutional Mechanism for Landslide Management
- Policy, Guidelines and Plans for Landslides Risk Management
- Landslide Identification, Investigation, Instrumentation and Monitoring,
- Early Warnings, Alerts and Communication Systems
- Search, Rescue and Relief Operations for Landslide victims
- Landslides Preparedness for pre, during and post landslide conditions (Do’s and Don’ts)
- Survival Skills for Disastrous Situations
• Prevention, Mitigation and Management of Landslide
• Response to Landslides
• Damage and Loss Assessment
• Cross cutting issues - Administrative, Legal, Financial, Technical, Social etc.
• Mainstreaming Landslide Risk Reduction with Development and Climate Change Adaptation in Hilly Regions
• Community Based Landslides Risk Management
• Standards, Codes, Regulations, Acts, Byelaws related to Landslides
• Case Studies and Best Practices
• Handouts/Exercises/Orientation Notes for Group Tasks, Guided Field Exercises, Role Plays and Mock Drills
• Resources, Links & Networks

Language

Medium of instruction is English. Further, all the presentations/ Demonstrations/ Drills/Exercises have been prepared in English but these can be translated into any local languages for understanding by layman. Interactions can also be in Hindi or any other vernacular languages.

Time Frame

Training shall be held for 5 days.

Training Methods

Lectures/Interactive Discussions, Power Point Presentations/slide shows, Brainstorming discussions / panel discussions / experience sharing / participatory learning, Needs Assessment, case studies, guided group exercises (table-top and simulation), hands on exercises/practicals, skill transfer, mock-drills, demonstration and exposure visit/guided field work.

Media and equipments

Computers, LCD Projector, Screen, Laser pointer, Overhead Projectors, White board, Flip Charts and a Stand, Markers, mike and speakers (PA system), Camera, GPS.

Performance Aids

Flip charts, lecture notes/hand-outs of presentations, questionnaires, check list, formats for data collection / templates, Exercises for Case studies.
Training Programme on COMPREHENSIVE LANDSLIDES RISK MANAGEMENT

Training Materials

Note pad, Pen, Folder/bag, CD, Sketch Pens, Flip Charts

Measures for Transfer of Learning

Each trainee shall submit an action plan to implement and impart training skills at his/ her organization. Trainees will be asked to submit a short term project with in one month to demonstrate their level of learning from the course and their efficacy in using the skills.

Assessment, Feedback and Validation Measures

During the course, questionnaires will be distributed to assess the level of learning of the participants. Daily session-wise evaluation will be done through recapitulation of learning of the previous day. Trainer / facilitator will also evaluate transfer of skills during role plays, exercises and mock drills by the participants. At the end of the course, the participants would be required to fill feedback form for their observations and comments. External validation shall be done through short term projects and feed back from the head of the sponsoring agency.

Benefits

1. Pool of trained human resources who can cater to the needs for assessing landslides risks and help in managing them or reducing their risks at district, state and national levels.
2. Reliable and credible system for landslide risk management would be developed.
3. Networking and co-ordination among various stakeholders will become stronger.

Cost of Training (per Course)

It includes TA/DA for Resource Persons, Training Kit, Stationery Cost, Expenditure on Field Visit, boarding and lodging charges for the participants, Transportation Charges, Photography, Xeroxing/Binding of Reading Material/Hand Notes, Hospitality Charges for Resource Persons, Communication Charges (mobile/ telephone/postage), Tutor Expenses, Miscellaneous/Contingent Charges, Administrative / Overhead Charges

Approximate Budget

Rs.63,000/- per training course
Day 1 - Learning Event for Learning Unit -1:
Landslide History, Morphology and Diagnostic Features

Topic 1-0: Registration
Enabling Objectives:
● Personal & Organizational Information about trainees
● Expectations from the Course
● Experience of participant

Contents
● Filling of Registration Form
● Compilation of registration record
● Profile of trainees/organizations

Time: 0930-1000 hrs. (30 min.)
Method: Proforma for registration
Facilitator: Training Assistant

Topic 1-2: Introduction and Inauguration
Enabling Objectives:
● Mutual Introduction of participants
● Experience sharing
● Course Introduction
● Significance of Programme & Paradigm shift

Contents
● Welcome to participants
● Experience sharing and Expectations
● Entry Behaviour
● Ground Rules
● Course Introduction
● Inaugural Address

Time: 1000-1130 hrs (90 min.)
Method: Mutual Interaction
Resource Person(s): Course Director and Guest Speaker
Learning Event for Learning Unit-1:
Basic Information on Landslides, History and Landslide Scenario

Training Objective:
(i) Basic Information about Landslides and Understanding about Landslides
(ii) Understanding history and scenario of landslide disasters - global, national, add state-wise

Objectives: At the end of this session, participants would be able to
1. Define landslides
2. Study the landslides features / morphology
3. Characterize different types of landslides
4. Inform about landslides scenario in the State/UT

Contents:
- Introduction to Terms/Concepts in CLRM
- Definition & Types of Landslides
- Landslide Features / Morphology

Time: 1145-1300 hrs (75 min.)

Method: Lecture, Presentation and Discussions with field examples

Topic - Landslide History and Scenario
Enabling Objectives: Learning about past landslide disasters and their impacts

Contents:
- History and Distribution of Landslides
- Lessons learnt from past landslides disasters

Time: 1400-1530 hrs (90 min.)

Method: Lecture, Presentation and Discussions with field examples

Topic - Landslide Morphology and Diagnostic Features
Enabling Objectives: Learning about parts of landslides
Diagnostic features of potential and relict landslides

Contents:
- History and Distribution of Landslides
- Lessons learnt from past landslides disasters
Time: 1545 - 1715 hrs (90 min.)
Method: Lecture, Presentation and Discussions with field examples
Summary of the Day-1: Recalling Day-1’s deliberations
Time: 1715-1730 hrs (15 min.)
Method - Mutual Interaction

End of Day - 1

Day 2 - Learning Event for Learning Unit - 2:
Factors affecting Landslides and Landslides Hazard Zonation

Training Objective:
(i) Landslides Indicators/precursors, Factors & Causes,
(ii) Landslides Database, Inventory and Hazard Zonation
(iii) Landslide Risk Assessment and Treatment

Session 2-1:
Topic 2-1 - Recapitulation of Day-1
Enabling Objectives: Recalling the learnings from last day
Contents:
- Recapitulation by participants
- Reference to the reading material

Method: Oral / Flip Chart
Time: 930-1000 hrs. (30 min.)

Session 2-2:
Topic 2-2 - Identification of Landslide Indicators and Precursors
Enabling Objectives: Understanding
- Field Indicators for slope Movements
- Precursors of Landslides

Contents:
- Enumeration of potential indicators for landslides
- Observations and interpretation of indicators
- Case examples from the field sites
- Experiences with landslide precursors
- Scope and limitation of landslide indicators and precursors for safety
Context

against landslides

Method:
Presentation and Discussion with field examples and sketches
Time: 1000-1100 hrs (60 min.)

Session 2-3:
Topic 2-3: Factors affecting occurrence of landslides
Enabling Objectives: Understanding
Factors & their types
Role and relation of different factors with the landslides
Content:
- Recognizing the factors affecting landslides
- Classifying factors as preparatory, controlling and triggering factors
- Discussing their relation with landslides using a case study

Method: Lecture, Presentation and Discussions with a Case Study
Time: 1115-1215 hrs (60 min.)

Session 2-4:
Topic 24- Factors and Causes of landslide
Enabling Objectives: Understanding factors and causes affecting
Dimensions of landslides (LxWxD)
Velocity of Landslides & Run-out distance
Time and duration of landslide activity

Contents:
Factors, causes and consequences of landslides
Method: Lecture and Discussions
Time & Duration: 1215-1300 hrs (45 min.)

Session 2-5:
Topic 25- Landslides Database and Inventory
Enabling Objectives: Understanding
Need, Status, Gaps and Strategy for Landslides Database and Inventories
Collection and Compilation of Data
Contents:
- Existing Landslides Database and Inventory
Training Programme on COMPREHENSIVE LANDSLIDES RISK MANAGEMENT

- Needs, Status, Gaps and Strategy to generate and update database - NDSS
- Template for Landslide Database
- Template for Landslide Inventory

Method: Lecture, Presentation and Discussions with Case Studies and Templates

Time and duration: 1400-1530 hrs. (90 min.)

Session 2-6:
Topic 26- Landslide Hazard Zonation, Risk Assessment and Treatment

Enabling Objectives: Information about LHZ
Landslide Risk Assessment
Options for Landslides Risk Treatment

Contents:
- Landslide Hazard Zonation
- BIS Code for LHZ
- A case study on LHZ
- Landslide Risk Assessment and Treatment

Method: Lecture, Presentation and Discussions with a Case Study

Time and Duration: 1545-1715 hrs. (90 min.)

Summary of the Day-2
Recalling Day-2’s deliberations
Mutual Interaction
1715-1730 hrs (15 min.)

End of Day-2

**Day 3 - Learning Event for Learning Unit 3 :**

Landslide Investigation, Monitoring and Remediation; Table-top Exercises

Training Objective:
(i) Landslide Investigation and Instrumentation
(ii) Landslide Monitoring and Warning system
(iii) Landslide Remediation
(iv) Table-top Exercises
Session 3-1

Topic 3-1: Recapitulation of Day-2

Enabling Objectives: Recalling the learnings from last day

Contents:
- Recapitulation by participants
- Reference to the reading material

Method: Oral / Flip Chart

Time and Duration: 930-1000 hrs. (30 min.)

Session 3-2:

Topic 3-2: Landslide Investigation and Monitoring

Enabling Objectives: Understanding
Preliminary Investigation and Monitoring
Detailed Investigation Planning
Instrumentation and Monitoring

Contents:
- Geological Investigations
- Geophysical Investigations
- Geotechnical Investigations
- Landslide Instrumentation

Method: Lecture, Presentation and Brainstorming Discussions

Time and Duration: 1000-1100 hrs (60 min.)

Session 3-3:

T 3-3: Options for Landslide Remediation

Enabling Objectives: Understanding
Landslide Remediation Practices
Options for Landslide Remediation
Mitigation methods for different types of landslides
Relevant standards and codes for landslide mitigation

Contents:
- Remedial Measures
- Landslides Management Practices in India
Training Programme on COMPREHENSIVE LANDSLIDES RISK MANAGEMENT

- Mitigation methods for different types of landslides
- Biotechnical and bioengineering measures

**Method:** Lecture, Presentation and Panel Discussions

**Time and Duration:** 1115-1300 hrs, (105 min.)

**Session 3-4:**
**Topic 3-4 - Orientation for Case Study on Landslides Management**

**Enabling Objectives:** Understanding Critical Issues related LRM activities

**Contents:**
(i) Orientation of participants to conduct TTE
(ii) Information about landslide
(iii) Grouping of participants - Team building
(ii) Rules for Conduct of TTE

**Method:** Lecture, Presentation and Discussions with a Case Study

**Time and Duration:** 1400-1430 hrs. (30 min.)

**Session 3-5:**
**Topic - Table Top Exercise on Landslide Management**

**Enabling Objectives:** Conduct of TTE
Facilitation, Observation and Monitoring

**Contents:**
- Understanding and utilization of information
- Interactions by individuals and discussion among the group
- Facilitation, Observation & Monitoring of TTE
- Action plan and implementation strategy for pre, during and post landslide risk management by the team

**Method:** Group Exercise (Table-top)

**Time and Duration:** 1430-1630 hrs (120 min.)

**Session 3-6:**
**Topic - Presentation and Feedback of TTE**

**Enabling Objectives:**- Comments on Technical/managerial content
Observations on attitudinal aspects and team spirit
Day 3

Summary of Day-3 activities and learnings
Instructions for Field Visit on next day

End of Day-3

Day 4 - Learning Event for Learning Unit- 4:

Field Exposure/Exercises, Mock drill and Videos/Documentary shows

Training Objective:
Field Visit to Landslide, Conduct of Simulation Exercise/Mock Drill, Videos on Evacuation and SRR, Demonstration of S&R techniques, first-aid and survival-skills

Session 4-1:
Topic - Recapitulation of Day-3

Enabling Objectives: Recalling the learnings from last day

Contents:
- Recapitulation by participants
- Reference to the reading material & discussions

Method: Oral / Flip Chart

Time and Duration: 930-1000 hrs. (30 min.)

Session 4-2:
Topic 42- Field Exposure to Landslide

Enabling Objectives: Understanding
Field Identification of Landslides
Studying landslide features/morphology
Observations & Data collection
Assessing factors & causes affecting landslide occurrence
Hazard, Vulnerability & Risk Assessment
Options for Risk Minimization

Contents:
- Features for landslide identification
- Landslide Morphology
- Landslide Characteristics & behaviour
- Elements at Risk & their degree of Vulnerability
- Risk Estimation, Classification, Prioritization and Communication
- Mock Drill / Simulation Exercise

Method: Exposure Visit / Guided Field Work / Simulation Exercise / Mock drill

Time and Duration: 1000-1530 hrs, (330 min.)

Session 4-3:
Topic- Presentation and Feedback of Field Visit and Simulation Exercise
Enabling Objectives- Comments on Technical/managerial content
Observations on attitudinal aspects and Team spirit

Contents:
- Group Presentations
- Comments and feedback
- Recommendations

Method: Flip Charts, Power Point Group Presentation

Time and Duration: 1630-1715 hrs

Summary of Day-4 activities and learnings
Next day plan
1715-1730 hrs (15 min.)

End of Day-4

Day 5 - Learning Event for Learning Unit 5:

Community Based Disaster Risk Management, Mainstreaming Landslide Risk Reduction, Capacity Development and Emerging issues

Training Objective:
(i) Community Involvement in Disaster Risk Management
(ii) Mainstreaming Landslide Risk Reduction
(iii) Capacity Development
Context

Session 5-1:
Topic- Recapitulation of Day-4
Enabling Objectives: Recalling the learnings from last day
Contents:
- Recapitulation by participants
- Reference to the reading material, field discussions and presentations
Method: Oral / Flip Chart
Time and Duration: 930-1000 hrs. (30 min.)

Session 5-2:
Topic- Community Based Disaster Risk Management
Enabling Objectives: Understanding
Role of community in disaster risk management
Tools and Technique for CBDRM
Case Study on CBDRM
Contents:
Methodology for CBDRM
Application to a locality
Case Example
Method: Video/slide show on community involvement in disaster risk reduction
Time and Duration: 1000-1030 hrs (30 min.)

Session 5-3:
Topic - Mainstreaming Landslides Risk Reduction
Enabling Objectives: Understanding
Inter-relation between disasters and development
Integrating disaster risk reduction with development
Contents:
- Relation between disasters and development
- Mainstreaming disaster risk reduction
- Issues and Strategies
Method: Video/slide Show on mainstreaming DRR with development
Time and Duration: 1030-1100 hrs, (30 min.)

Session 5-4:
Topic- Capacity Development and Emerging Issues
Enabling Objectives: Landslide Education and Training
Landslide Awareness and Preparedness
Capacity Development
Emerging Issue

Contents:
Training and Capacity Development for Landslides Risk Reduction
Emerging Issues
Method: Slide show
Time and Duration: 1115-1215 hrs (60 min.)

Session 5-5:
Topic - Networking, Linkage and Coordination
Enabling Objectives: Landslide Networks and Links
Coordination between different stakeholders

Contents:
- Information Landslide Knowledge Networks
- Information about Landslide Resources Networks
- Linkage and coordination activities
Method: Practical Demonstration on First Aid and survival Skills
Time and Duration: 1215-1300 hrs (45 min.)

Session 5-6:
Topic- A Case Study on Community Based Landslides Risk Management & LMP
Enabling Objectives: Understanding
Community Involvement in LRM
Format for LRMP

Contents:
- Aims and Objectives of CBLRM
Context

- Methodology for field operation
- RRA/PRA/PLA Tools
- Context specific issues
- Template for LMP

**Method:** Lecture, Presentation and Discussions

**Time and Duration:** 1400-1500 hrs. (60 min.)

**Session 5-7:**

**Topic:** Cross cutting Issues and Mainstreaming DRR with Development & Climate Change

**Enabling Objectives:** Issues related to discipline, sectors, levels, boundaries, policies etc.

**Contents:**
- Inter-disciplinary studies
- Cross-sectoral and multi-level approach
- Transboundary Issues
- Advocacy, Policy, Planning & guidelines

**Method:** Group Discussions

**Time and Duration:** 1500-1600 hrs (60 min.)

**Session 5-8:**

**Topic:** Landslide Quiz

**Enabling Objectives:** Knowledge Check

**Contents:** Knowledge Check

**Method:** Slide Show, Question-Answers

**Time and Duration:** 1600-1645 hrs

**Session 5-9:**

Evaluation, feedback, certification and valediction

**Contents:**
- Feedback from participant
- Post-training assignment

**Method:** Follow-up Strategy

**Time and Duration:** 1645-1730 hrs (45 min.)

**End of the Course**
A. Introduction

Landslides occur in all hilly terrains in response to a wide variety of conditions and triggering processes like heavy rainstorms, cloudbursts, earthquakes, floods, cyclones and haphazard human activities. CRED data indicates 8,658 human casualties due to landslides and avalanches between 1990 and 1999 but it appears to be significantly under-estimated. As landslides are frequent and widespread, the annual cumulative losses worldwide amount to tens of billions of USD in terms of lost property, environmental damage, repair works, and the maintenance of defence measures (source: Page 61, World Atlas of Natural Hazards by Bill McGuire, Paul Burton, Christopher Kilburn and Oliver Willets). The frequency of landslides is strongly influenced by the return periods of triggering events like rainfall and earthquakes.

More than 5000 people are buried alive under landslides and economic losses of >4 bn USD are suffered every year globally. Continent-wise, Asia suffers the maximum damages / losses due to landslides and among the Asian countries, South Asian nations are the worst sufferers and even among South Asian countries, India is one of the worse affected by landslides.

In India, nearly 15% of its territory (covering about 0.49 million sq.km) is prone to various degrees of landslide hazard (GSI, 2001), frequently affecting the human life, livelihood, livestock, living places, structures, infrastructure, and natural resources in a big way. In addition to direct and indirect losses, landslides cause significant environmental damage, societal disruption and strategic concern. Landslides are spread over 22 States and 2 UTs including J&K, Himachal, Uttarakhand, Arunachal, Assam, Meghalaya, Mizoram, Manipur, Nagaland, Sikkim, Tripura, Kerala, Karnataka, Tamilnadu, Andhra Pradesh, Goa, Maharashtra, Madhya Pradesh, Chhatisgarh, Andeman & Nicobar and Puducherry. The most sensitive areas are Himalayan belt, Nilgiris, Western and Eastern Ghats. Landslides constitute a serious hazard that causes substantial human and financial losses in the country. It is estimated that on an average about 500 lives are lost and costs approximately Rs.300 crores annually.
Landslides can happen not only in isolation but also along with or as a consequence of other disasters like earthquakes, floods, lightning, cloud-burst, forest fires, dam / lake bursts etc. In such cases, landslide losses are normally included within the primary disaster and are not dealt separately. Hence, most of the reported estimates on landslides losses are found to be quite lower than the actual impacts of landslides on the society as a whole.

With growing population and human interventions in terms of developmental activities over unstable slopes, landslides pose increasing risk to human life, buildings, structures, infra-structures and environment. Large scale deforestation along with faulty management practices have led to high vulnerability to landslides in many regions of the country. Human activities relating to expansion on unsafe locations, unscientific mining, haphazard construction of roads, dams and river training works ignoring natural features contribute to increased intensity of landslides. The absence of awareness and non-availability of large scale landslide hazard maps may catch people unaware especially when the first time landslides strike.

As individual landslides usually affect limited local areas and residents, damage resulting from landslide hazards was not recognized as a problem of national importance and were not addressed on a national basis. The absence of coordinated national approach to mitigating the detrimental effects of landslides resulted in a reduced ability of the States and Local Government agencies to apply the important lessons learnt, often at considerable expense, in other parts of the country.

As a result, the need for a national strategy has been strongly felt and worked upon now by the National Disaster Management Authority through National Disaster Policy and Guidelines on Landslides. Being cognizant of the diversity of issues associated with national landslides problem that arise from both regional considerations and considerable variations in the institutional capability and responsibility at regional and local levels, inputs from a wide variety of stakeholders are essential. Strengthening the process of landslide assessment, investigation, mapping and management will have far reaching effects in reducing landslide losses. NIDM, the nodal institute dealing with disasters is planning to undertake such projects in order to stimulate necessary activities across the country and create a nodal platform to deliver trainings on various aspects of landslides risk management and also create a network of resources persons / experts who can contribute in this activity. It would pave way for effective decision making and planning.
micro level mapping for various developmental and regulatory activities in hilly terrains.

NIDM, thus, aims to work in the following directions to make the hilly terrains and coastal areas free from landslide disasters.

- To promote the use of landslide risk analysis techniques to guide loss reduction efforts at the State and Local Levels.
- To play a vital role in evaluating methods, setting standards, and advancing procedures and guidelines for landslide hazard maps and assessments.
- To provide tools for landslide hazards mitigation and promote basic research on monitoring techniques and on aspects of landslide process mechanics.
- To improve education, training and awareness of landslide hazards and mitigation options for decision makers, professionals, and the general public.
- To integrate and mainstream landslide risk management with development and climate change in a multi-hazard perspective involving interdisciplinary and cross-sectoral partnership approach.
- To produce the implementation and management plans that will provide the practical basis for an effective national strategy that can be applied at local levels.
- To support advocacy, policy, guidelines and plans for landslides risk management at different levels among various stakeholders.
- To develop workable partnerships with States, District and Local Level Governments and Non-Governmental Organizations as well as professional and other stakeholders.

**B. Landslide Scenario in India**

Landslides are a threat to our settlements and infrastructure, farms and fields, vast stretches of border roads and railway lines, hydro-electric, water supply, and transmission line projects, aerial ropeways, open cast mines, tunnels, heritage buildings and worshipping / holy places, pilgrim routes and tourist spots.

The vulnerability to landslides can be reduced by spreading mass awareness and culture of safety through careful land-use planning, timely and appropriate engineering intervention, conscientious maintenance of slope
Comprehensive Landslides Risk Management

and connected utilities, early warning, public awareness, and preparedness. There is a need to develop the culture of quick response to manage disasters and reduce the impacts.

The Ambutia landslide, located on the tea garden clad picturesque hill slopes around the Kurseong town in the Darjeeling district, West Bengal is probably the largest landslide in Asia. As the pressure of population rapidly grew, more and more of human settlements, roads, dams, tunnels, water reservoirs, towers and other public utilities have to come up. The network of roads in the Himalayan region today is well over 50,000 km. A large number of dams have been built in the Himalaya. For example, the dam projects over the Ganga and its tributaries in the hills alone exceed two dozen. A number of tunnels, microwave, TV, transmission and communication towers also dot the hilly areas. Quarrying and mining, for example, in the Doon valley lead to deforestation and bare lands, Jhiroli (Almora) and Chandhak (Pithoragarh) have inflicted heavy damages to slopes and the associated environment.

Landslides have been occurring along NH-1A and NH-1B in Jammu & Kashmir, Rishikesh- Badrinath pilgrimage route in Uttarakhand Himalaya, many areas in Darjeeling & Sikkim Himalaya, Dimapur-Imphal and Shillong-Silchar National Highways in north-eastern region. These have been disastrous and have caused enormous economic losses and affected the social fabric of the region for a long time.

Recent landslides that have catastrophic effects in terms of life, economy and environment include Kapkot Landslide (2010), Leh Debris Flow (2010), Nilgiri Landslide (2009) and La-Jhekla Debris Flow (2009), Karwar Landslide (2009), Ghanvi village Landslide (2007), Sakinaka Landslide in Mumbai, Konkan landslides (2005), Varunavat Landslide (2003), Budha Kedar Debris Flows (2001), Malpa Landslide (1998), Kaliasaur Landslide (1984), Zubza and Mao Seng-Song Landslides along Dimapur- Imphal National Highway, Sonapur Landslide along Shillong- Silchar National Highway. Other examples of devastating landslides include Amboori landslide in Thiruvanantapuram district, Kerala; Runnymede, Hospital, Glenmore, Coonoor and Karadipallam Landslides in Nilgiris district, Tamil Nadu

Instances of co-seismic landslides particularly in the Himalayan terrain and North-eastern part of the country are not uncommon. Shillong earthquake (1897), Kangra earthquake (1905), Bihar-Nepal Earthquake (1934), Assam earthquake (1950), Uttarkashi earthquake (1991) and Chamoli earthquake (1999) generated numerous co-seismic landslides over vast areas. Similarly,
October 2005 Kashmir earthquake generated numerous landslides both in Pakistan territory as well as in Indian territory. More recently, the Sikkim-East Nepal earthquake on 18 September 2011, triggered numerous landslides in the Sikkim state.

Some of the landslides block the drainage courses and form natural dams known as landslide dams. A few important ones are the Gohana Gad landslide dam that blocked Birehiganga in 1893, landslide blockage on river Patalganga in 1970 which led to Alaknanda tragedy, Naptha-Jhakhri landslide on Satluj that caused huge losses to the Nathpa-Jhakhri hydroelectric project, and the devastating landslide that blocked the river Parechhu in Tibet that caused large scale floods in Himachal Pradesh in 2005 when this natural dam breached.

C. Impact of Landslide Disasters

The landslide disasters have both short term and long term impacts on society and environment. The former account for the loss of life and property at the site and the latter include landscape changes that can be permanent, including loss of cultivable land and environmental impact in terms of erosion and soil loss, leading to population shift and relocation of establishments.

Like in any other disaster, the most affected are the socio-economically weaker sections of the society who inhabit the vulnerable areas. They have a meager source of livelihood, which when wiped out by a hazard, leaves them without any food and shelter. Apart from this, the injury and the casualties add to the woes of the affected families. The biggest loss is that of properties of individuals and of the government as well as damage/ destruction of heritage structures.

The frequent obstructions caused to the movement of traffic by numerous landslides during rainy season for days together, particularly in the Himalayan terrain and north-easterly region of the country, brings untold miseries to the people inhabiting the villages and townships in the landslide prone hilly terrains.

The landslides also reduce the capacity and effective life of hydroelectric and multipurpose projects by adding enormous amount of silt load to the reservoirs.

Landslide dams result in flooding of large upstream areas. Further, if the dam fails, it causes flooding and large scale devastation in downstream areas. Also,
solid landslide debris can “bulk” or add volume and density to otherwise normal stream flow or cause channel blockages and diversions creating flood conditions or localized erosion. Landslides can also cause overtopping of dams resulting in flash floods and/or reduced capacity of reservoirs to store water, for examples are Gohna and Parechhu Lake bursts.

D. Landslide Hazard Management in India

Landslide hazard management in India had so far been confined to adhoc solutions of the site specific problems and implementation of immediate remedial measures including debris removal and dumping them either down slope or into the river. The aim of the present training is to manage the landslide hazard through an institutional mechanism and following a systematic approach that includes both short term and long term planning and treatment of landslide problems involving hazard, vulnerability and risk assessment approaches.

Landslide hazard management involves the measures to avoid or mitigate the risk posed by the landslide hazard. The most important role in this process is played by the local government machinery. Once this body receives the information about the probability of landslide occurrence within its jurisdiction, it initiates steps to warn the communities living in the area about the risk involved and tries to convince landowners and building occupiers to shift to safer places. Moreover, further development should be avoided in such high risk zones. The mitigation strategies might not be possible in every landslide hazard prone area both due high cost of the land there and indifferent attitude of the public. The efforts to reduce the risk are also made by road construction and maintenance agencies by implementing the treatment measures.

There is, however, a need to pre-empt the disaster by disseminating information available before it strikes and same should be emphasized by all states specially those routinely affected by multi-hazards.

E. Landslides in other countries

In Japan alone, an average of 90 lives are lost annually from debris flows (Takahashi, 1981). In 1970, a debris avalanche (a rapidly moving form of debris flow) triggered by an earthquake, completely destroyed the city of Yungay, Peru, killing an estimated 17,000 people and burying the whole city under 5m of mud and debris (Plafker and Erickson, 1978). Other countries with chronic losses from debris flows are USA, Indonesia, Tanzania, Norway, Sweden, Denmark, Costa Rica, China, Brazil, Ireland, Romania, Japan, Bangladesh, New Zealand, Russia etc.
Landslides have caused over 600 deaths across Canada since the middle of the 19th century. In addition, communities have been damaged, lines of communication have been severed, and the resource base has been significantly impacted. Recent studies of the geographic distribution of the impact of landslides in Canada has indicated that the Canadian Cordillera, comprising about one-fifth of Canada’s land mass, is the region most prone to damaging landslides.

The southeastern Cordillera (roughly defined by the Trans-Canada Highway to the north, the Foothills to the east and the Okanagan Valley to the west) has been the site of a number of catastrophic landslides including the 1903 Frank Slide, Canada’s worst landslide disaster. The region is crossed by national strategic transportation corridors, has important natural resources, and has extensive areas of designated natural heritage. The record of damaging landslide events in historical time has been compiled from existing case history documents, archival information, and information supplied by transportation companies and government agencies. The record has been assembled in a relational database. Some damaging landslide types have been identified as follows; rock avalanches, rockfalls, rainfall-triggered debris flows and debris avalanches, landslides in built slopes, and landslides in slopes consisting of glacio-lacustrine deposits. Deforming rock slopes, however, constitute a hazard that is difficult to assess.

F. Benefits of Good Landslide Management Practices

Several countries like Japan, Hong Kong, Switzerland and USA have made good attempts in prevention and management of landslide risk through various measures such as landuse, construction and development controls. Slosson and Krohen (1977) have demonstrated the benefits of good landslide management practices with the following example from California as given in the Table 1 below.
Table 1: Landslide & Flood Damages to Hillside Homes in Los Angeles County, California

<table>
<thead>
<tr>
<th>Construction Dates and Legal Requirements</th>
<th>Number of Homes built on Hillside sites</th>
<th>Damaged Homes</th>
<th>Average Cost Prorated for Total Number of Homes Built</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent of Total</td>
<td>Total Damage</td>
</tr>
<tr>
<td>Pre-1952: No Legal requirements for soils engineering or engineering geological studies</td>
<td>10,000</td>
<td>1,040</td>
<td>10</td>
</tr>
<tr>
<td>1952-1963: Soils engineering studies required. minimum engineering geology studies</td>
<td>27,000</td>
<td>350</td>
<td>1.3</td>
</tr>
<tr>
<td>1963-1969: Extensive engineering geology and soils engineering studies required</td>
<td>11,000</td>
<td>17</td>
<td>0.15</td>
</tr>
</tbody>
</table>
1.1 Introduction

Landslides are simply defined as down slope movement of rock, debris and/or earth under the influence of gravity. This sudden movement of material causes extensive damage to life, economy and environment. It is the most common and universally accepted collective term for most slope movements of the massive nature. The term has sometimes been considered unsuitable as the active part of the word denotes sliding, whereas it connotes even movements without sliding like fall, topple, flow etc.

Other terms which have been used by different stakeholders in place of landslides are mass wasting, mass movements, slope failures etc. Similarly the slope materials are also classified differently by various researchers. For example, *Sharpe (1938)* defined landslides as the perceptible downward sliding or falling of a relatively dry mass of earth, rock or a mixture of the two. *Varnes (1978)* preferred the term ‘Slope Movements’ as it does indicate process and defined it as a downward and outward movement of slope forming materials under the influence of gravity. *Brunsden (1984)* preferred the term ‘mass movement’ and distinguished this from mass transport as being a process which did not require a transporting medium such as air, water or ice etc. *Cruden (1991)* defined landslides as a movement of mass of rock, earth or debris down a slope. However, the classification of slope processes and slope materials as proposed by cruden and *Varnes (1996)* has been widely accepted and is given below for the reader’s reference.

### Table 1.1: Classification of slope processes and materials *(after cruden and Varnes, 1996)*

<table>
<thead>
<tr>
<th>Type of Movement</th>
<th>Type of Material</th>
<th>Type of Material</th>
<th>Type of Material</th>
<th>Type of Material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bedrock</td>
<td>Coarse Grained Soil or Debris</td>
<td>Fine Grained Soil</td>
<td></td>
</tr>
<tr>
<td>Falls</td>
<td>Rock Fall</td>
<td>Debris Fall</td>
<td>Earth Fall</td>
<td></td>
</tr>
<tr>
<td>Topples</td>
<td>Rock Topple</td>
<td>Debris Topple</td>
<td>Earth Topple</td>
<td></td>
</tr>
<tr>
<td>Slides</td>
<td>Rotational</td>
<td>Rock Slump</td>
<td>Debris Slump</td>
<td>Earth Slump</td>
</tr>
<tr>
<td></td>
<td>Translational / Wedge</td>
<td>Rock Slide</td>
<td>Debris Slide</td>
<td>Earth Slide</td>
</tr>
</tbody>
</table>
It is important to distinguish among the different types of landslides to be able to understand how to deal with each of them. The ways to identify and mitigate different types of landslides are often different.

### 1.2 Morphology of Landslides

Before we discuss about different types of landslides, it would be good to learn about the morphology of landslides and its various features/parts as given below.

![Figure 1.1: An idealized slump-earth flow showing commonly used nomenclature for labeling the parts of a landslide (Source: USGS)](image)

#### 1.2.1 Parts of Landslides - Description of Features

- **Accumulation** - The volume of the displaced material, which lies above the original ground surface
- **Crown** - The practically undisplaced material still in place and adjacent to the highest parts of the main scarp
Depletion - The volume bounded by the main scarp, the depleted mass and the original ground surface

Depleted mass - The volume of the displaced material, which overlies the rupture surface but underlies the original ground surface

Displaced material - Material displaced from its original position on the slope by movement in the landslide. It forms both the depleted mass and the accumulation.

Flank - The undisplaced material adjacent to the sides of the rupture surface. Compass directions are preferable in describing the flanks, but if left and right are used, they refer to the flanks as viewed from the crown.

Foot - The portion of the landslide that has moved beyond the toe of the surface of rupture and overlies the original ground surface.

Head - The upper parts of the landslide along the contact between the displaced material and the main scarp.

Main body - The part of the displaced material of the landslide that overlies the surface of rupture between the main scarp and toe of the surface of rupture.

Main scarp - A steep surface on the undisturbed ground at the upper edge of the landslide, caused by movement of the displaced material away from undisturbed ground. It is the visible part of the surface of rupture.

Minor scarp - A steep surface on the displaced material of the landslide produced by the differential movement within the displaced material.

Original ground surface - the surface of the slope that existed before the landslide took place.

Surface of separation - The part of the original ground surface overlain by the foot of the landslide

Surface of rupture - The surface that forms the lower boundary of the displaced material below the original ground surface.

Tip - The point of toe farthest from the top of the landslide.

Toe - The lower, usually curved margin of the displaced material of a landslide, it is the most distant part from the main scarp.

Top - The highest point of contact between the displaced material and the main scarp.
Landslides Introduction

Toe of surface of rupture - The intersection (usually buried) between the lower part of the surface of rupture of a landslide and the original ground surface.

Zone of accumulation - The area of landslide within which the displaced material lies above the original ground surface.

Zone of depletion - The area of the landslide within which the displaced material lies below the original ground surface.

1.3 Landslide types based on process of failure

Based on process types, there are five types of landslides i.e. Fall, Topple, Slide, Spread, Flow and Subsidence.

1.3.1 Fall: is a very rapid to extremely rapid movement which starts with detachment of material from steep slopes such as cliffs, along a surface on which little or no shear displacement takes place (Figures 1.2 and 1.3). The material then descends through the air by free falling, bouncing or rolling onto the slopes below.

- The detachment of soil or rock from a steep slope along a surface on which little or no shear displacement takes place.
- Movement very rapid to extremely rapid.
- Free fall if slope angle exceeds 76 degrees and rolling at or below 45 degrees.

However, in order to identify the potential falls and relict falls, Table 1.2 may be referred.
1.3.2 Topple: involves overturning of material. It is forward rotation of the slope mass about a point or axis below the centre of gravity of the displaced mass. Topples range from extremely slow to extremely rapid movements (Figs. 1.4 to 1.6).

- The forward rotation out of the slope of a mass or a rock about a point or axis below the centre of gravity of the displaced mass.
- Movement varies from extremely slow to extremely rapid.
- Driven by gravity and sometimes by water or ice in cracks in mass.

### Table 1.2: Diagnostic features of falls

<table>
<thead>
<tr>
<th>Potential Falls</th>
<th>Relict Falls</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Steep to vertical slopes, overhanging; undercut; open cracks close to slope face</td>
<td>Where rockfalls have taken place these may be curved hollows, beams, bridges of rock on buttresses.</td>
</tr>
<tr>
<td>2. Dip of discontinuities dip or open towards the free slope face are vulnerable</td>
<td>Look for piles of debris, loose rock, scree slopes, open-work rock textures in colluvium, detached boulders, massive debris in valley floors, valley dams.</td>
</tr>
<tr>
<td>3. Discontinuities with gouge or other soft infillings and interbedded materials are common locations</td>
<td>If the fall source is mainly debris, then the relict form may be boulders set in a redistributed matrix or colluvium</td>
</tr>
<tr>
<td>4. Falls occur where high water pressures are possible. Melting permafrost or seasonally frozen faces are vulnerable areas</td>
<td></td>
</tr>
<tr>
<td>5. Any eroded slope in debris or soil is vulnerable. Such slopes rapidly unload or weather so that boulders fall in heavy rains or similar disturbances.</td>
<td></td>
</tr>
</tbody>
</table>
However, in order to distinguish between potential and relict topples, some of the diagnostic features as referred in Table 1.3 can be used.
Table 1.3: Diagnostic features of topples

<table>
<thead>
<tr>
<th>Potential</th>
<th>Relict</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  A free face, steep slopes or cliff with sufficient unloading potential</td>
<td>Cliff top may be marked by residual, unemployed tension cracks, partially detached columns.</td>
</tr>
<tr>
<td>2  Sufficient height (weight) relative to the width of base to provide disturbing force</td>
<td>Rock face will show open vertical cracks. Cracks may have chaotic infill from overlying material</td>
</tr>
<tr>
<td>3  Sufficient rock strength to allow a column to stand. Usually hard or coherent rock layer overlying a weaker stratum</td>
<td>Base of cliff shows disturbed strata or bulging material</td>
</tr>
<tr>
<td>4  Strong vertical joint development which divides face into columnar units; Strong jointing or unloading tension cracks parallel to face</td>
<td>Where a column has fall the weathering detail on the face may be less well developed. Very fresh scars will be smooth.</td>
</tr>
<tr>
<td>5  Critical dip in basal materials</td>
<td>Debris will be very chaotic. Huge boulders or partially broken columns will be scattered across the lower slopes. The texture will be coarse with open works and extensive voids.</td>
</tr>
</tbody>
</table>

1.3.3 Slide: movement of material along a recognizable shear surface e.g. translational and rotational slides (Figs. 1.7 to 1.10).
- Downslope movement of a soil or mass occurring dominantly on surfaces of or on relatively thin zones of intense shear strain.
- The sign of ground movement are cracks of the original ground.

Fig. 1.7: Sktech showing movement parallel to planes of weakness and occasionally parallel to slope.
Landslides Introduction

**Modes of Sliding:**
- Translational / planar slides
- Wedge slides
- Rotational slide

![Fig. 1.8: Planar rockslide](image1)
![Fig. 1.9: Wedge rockslide due to intersection of two joint planes facing towards valley](image2)

**Table 1.4: Diagnostic features of rotational slides**

<table>
<thead>
<tr>
<th>Potential</th>
<th>Relict</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Single rotational slides require steep slopes, undercut areas, erosion by streams and the sea</td>
<td>Hummocky ground</td>
</tr>
<tr>
<td>2 Rise in piezometric surface or changes in water regime</td>
<td>Toe area recognisable as a pronounced lobe with a steep front</td>
</tr>
<tr>
<td>3 Usually, unconsolidated clays and uniform clay outcrops</td>
<td>Crown will have a back-tilted or horizontal surface.</td>
</tr>
<tr>
<td>4 Multiple slides commonly occur where permeable rocks overly impermeable rocks</td>
<td>Hollows infilled with washed debris and organic material common at head</td>
</tr>
<tr>
<td>5 A weak layer is usually required to allow development of a common shear surface for multiple slides</td>
<td>All irregularities will be smoothed out and infilled in time. Form may be completely erased to a smooth slope, but the structure and shear surface will remain beneath the ground</td>
</tr>
<tr>
<td>6 Retrogressive unloading could generate new slides</td>
<td>Tension cracks may be visible at the head</td>
</tr>
</tbody>
</table>
1.3.4 Flow: is a landslide in which the individual particles travel separately within a moving mass (Figs. 1.11 to 1.13).

- Spatially continuous movement, in which surfaces of shear are short-lived, closely spaced and usually not preserved.
- Flows are differentiated from slides, on the basis of water content, mobility and evolution of movement.

Features for recognition of flows are

i. Crown may have few cracks.

ii. The main scarp typically has serrated or funnel shaped upper part; is long and narrow, bare and commonly striated.

iii. Flanks are steep and irregular in the upper part; may have levees built up in the middle and lower parts.

iv. The body has flowlines, follow drainage ways, is sinuous, and is very long compared to width.

v. The toe spreads laterally in lobes; if dry, may have steep front.
Fig. 1.11: Sketch showing Viscous to fluid-like motion of debris, often channeled

Modes of Flow

- Open-slope debris flow
- Channeled flow

Fig. 1.12: Debris flow after a cloudburst at Balta, Uttarakhand

Fig. 1.13: Debris Flow near Sikkim Supreme Factory on NH-31 A, Sikkim
1.3.5 Spread

- Sudden movement on water-bearing seams of sand or silt overlain by homogeneous clays or loaded by fills.
- May result from liquefaction or flow of softer material.

**Modes of Spreading:**

- Block Spreads
- Liquefaction spreads
- Complex spreads
  - Lateral Spreading: is usually used to describe the lateral extension of a cohesive rock or soil mass over a deforming mass of softer underlying material in which the controlling basal shear surface is often not well defined.
  - Rock Spreading: is the result of deep seated, plastic deformation in a rock mass, leading to extension at the surface. e.g. cambering, horsts and grabens and valley bulging.
  - Soil Spreading: takes place as a result of plastic deformation in the soil mass, only it occurs generally in response to a loss of strength, and by the application of stresses over a long period of time.

1.3.6 Slump

It is a type of rotational failure on slopes. The trees bends or fall backwards on towards the slope, as shown in the figure 1.14.

![Fig. 1.14: Sketch showing slump type failure](image)
1.3.7 Creep

Very slow rates of slope movements, usually a few millimeter per year, that is imperceptible in nature) are covered under this category (Fig. 1.15).

However, one may find landslides that do not fall directly under any of these typical singular types of slope failures. Such landslides may be composite, complex or multi-tier. The following examples indicate some mixed processes

1.3.8 Multi-tier / Multi-rotational landslides - When more than one main scars appear in a landslide site and slope mass has more than one slip surface along which movement takes place (Fig.1.16).
1.3.9 **Complex Landslides** - Those landslides where the nature of failure process is not consistent but changes with time (Fig. 1.17). For example, a landslide that begins with rock sliding changes its nature to a rock-fall due to steepening of slopes during a failure, may again result into a debris flow due to formation of a channel during the process of past failures. Thus, it becomes, often very difficult to prevent and control such complex landslides. It requires a persistent study to understand the causes of such landslides properly. These landslides are also found to be chronic and recurring in nature. For example, Kaliasaur landslide in Alaknanda valley, Uttarakhand has displayed complex failure.

![Complex Landslide at Kaliasaur, Alaknanda Valley, Uttarakhand](image)

**Fig. 1.17:** Complex Landslide at Kaliasaur, Alaknanda Valley, Uttarakhand

1.3.10 **Composite Landslides** - The slopes which fail in different manners simultaneously at the same site are termed as composite landslides (Fig. 1.18). These landslides display a composite nature as different parts of the landslide indicate a different process type. The types of failure vary due to changes in slope aspect, gradient, heterogeneity in slope mass, landcover, structural / tectonic controls etc. For example, Matli landslide in Bhagirathi valley, Uttarakhand is an example of composite landslide.
In addition to the classification based on process types and their combination, the landslides can be classified in more different ways. Some examples of such landslide classifications proposed by different researchers, are given here for better understanding of the slope failures.

According to age (Huang, 1983), slope movements are classified into contemporary, dormant and fossil movements. Contemporary movements are generally active and relatively easily recognizable by their configuration (the surface forms produced by mass movements are expressive) and not affected by rainwash and erosion. Dormant movements are usually covered by vegetation or disturbed by erosion so that the traces of their last movement are not easily discernible. However, the causes of their origin do not die down and the movement may be renewed. Fossil movements generally developed in the Pleistocene or earlier periods, under different morphological and climatic conditions, cannot be repeated.

According to stage (Huang, 1983), slope movements can be divided into initial, advanced and exhausted movements. At the initial stage, the first signs of the disturbance of stability (equilibrium) appear and cracks in the upper part of the slope develop. In advanced stage, the loosened mass is propelled into motion and slides downslope. In the exhausted stage, the accumulation of the slide mass creates temporary stabilization (equilibrium) conditions.

The degree of activity of landslides enables an assessment of the possibility of future movement. Erskine (1973) provided the following definitions on various degrees of activity. Active slopes represent those moving at the present time or within last cycle of seasons. Whereas Inactive slopes have not moved within the
last cycle of seasons and are therefore, dormant. They may later renew their activity or remain dormant for so long that their features become degraded. The following table outlines the major differences between active and inactive landslides.

**Table 1.5: Features indicating Active and Inactive Landslides**

<table>
<thead>
<tr>
<th></th>
<th>Active</th>
<th>Inactive</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Scarps, terraces and crevices with <em>sharp edges</em></td>
<td>Scarps, terraces and crevices with <em>rounded edges</em></td>
</tr>
<tr>
<td>2</td>
<td>Crevices and depressions <em>without secondary infilling</em></td>
<td>Crevices and depressions infilled with <em>secondary deposits</em></td>
</tr>
<tr>
<td>3</td>
<td><em>Secondary mass movement</em> on scarp faces</td>
<td><em>No secondary mass movement</em> on scarp faces</td>
</tr>
<tr>
<td>4</td>
<td>Surface of rupture and marginal shear planes show <em>fresh slickensides and striations</em></td>
<td>Surface of rupture and marginal shear planes show <em>old or no slickensides and striations</em></td>
</tr>
<tr>
<td>5</td>
<td><em>Fresh fractured surfaces</em> on blocks</td>
<td><em>Weathering</em> on fractured surfaces of blocks</td>
</tr>
<tr>
<td>6</td>
<td><em>Disarranged drainage system</em>; many ponds and undrained depressions</td>
<td><em>Integrated</em> drainage system</td>
</tr>
<tr>
<td>7</td>
<td><em>Pressure ridges in contact with slide margins</em></td>
<td><em>Marginal fissures and abandoned levees</em></td>
</tr>
<tr>
<td>8</td>
<td><em>No soil development</em> on exposed surface of rupture</td>
<td><em>Soil development</em> on exposed surface of rupture</td>
</tr>
<tr>
<td>9</td>
<td>Presence of <em>fast growing vegetation</em> species</td>
<td>Presence of <em>slow growing vegetation</em> species</td>
</tr>
<tr>
<td>10</td>
<td><em>Distinct vegetation differences</em> <code>on</code> and <code>off</code> slide</td>
<td><em>No distinction</em> between vegetation <code>on</code> and <code>off</code> slide</td>
</tr>
<tr>
<td>11</td>
<td>Tilted trees with <em>no new vertical growth</em></td>
<td>Tilted trees with <em>new vertical growth above inclined trunk</em></td>
</tr>
<tr>
<td>12</td>
<td><em>No new supportive, secondary tissue</em> on trunks</td>
<td><em>New supportive, secondary tissue</em> on trunks</td>
</tr>
</tbody>
</table>

**1.4 Other Classifications**

Besides the process based classification, the landslides have also been categorized based on velocity of landslides (Table 1.6), depth of landslides (Table 1.7) and area affected by landslides (Table 1.8) etc.
### Table 1.6: Proposed Landslide Velocity Scale *(Varnes, 1996)*

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Velocity (mm/sec)</th>
<th>Typical Velocity</th>
<th>Probable Destructive Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Extremely Rapid</td>
<td>$\geq 5 \times 10^3$</td>
<td>$\geq 5$ m/sec</td>
<td>Catastrophe of major violence; buildings destroyed by the impact of displaced material; many deaths; escape unlikely</td>
</tr>
<tr>
<td>6</td>
<td>Very Rapid</td>
<td>$\geq 5 \times 10^1$</td>
<td>$\geq 3$ m/sec</td>
<td>Some lives lost; velocity too great to permit all persons to escape</td>
</tr>
<tr>
<td>5</td>
<td>Rapid</td>
<td>$\geq 5 \times 10^{-1}$</td>
<td>$\geq 1.8$ m/hr</td>
<td>Escape evacuation possible; structures, possessions and equipment destroyed</td>
</tr>
<tr>
<td>4</td>
<td>Moderate</td>
<td>$\geq 5 \times 10^{-3}$</td>
<td>$\geq 13$ m/month</td>
<td>Some temporary and insensitive structures can be temporarily maintained</td>
</tr>
<tr>
<td>3</td>
<td>Slow</td>
<td>$\geq 5 \times 10^{-5}$</td>
<td>$\geq 1.6$ m/year</td>
<td>Remedial construction can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase</td>
</tr>
<tr>
<td>2</td>
<td>Very Slow</td>
<td>$\geq 5 \times 10^{-7}$</td>
<td>$\geq 16$ mm/year</td>
<td>Some permanent structures undamaged by movement</td>
</tr>
<tr>
<td>1</td>
<td>Extremely Slow</td>
<td>$&lt; 5 \times 10^{-7}$</td>
<td>$&lt; 16$ mm/year</td>
<td>Imperceptible without instruments; construction possible with precautions</td>
</tr>
</tbody>
</table>

**Speed of a running man is ~5 m/sec** (It matches approximately with velocity of extremely rapid and rapid landslides)
1.5 Causal Factors for Landslides - There can be several different causative factors for the occurrence of landslides which may work individually or collectively to cause a landslide. Broadly these factors can categorized into ground conditions, geomorphological processes, physical processes and man-made processes. A brief list of these causal factors is given in the table below.

Table 1.7: Classification of Landslides on the basis of its depth

<table>
<thead>
<tr>
<th>Depth of slide below surface</th>
<th>Class Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 &lt;1.5 m</td>
<td>Surficial Slide</td>
</tr>
<tr>
<td>2 1.5 m - &lt;5 m</td>
<td>Shallow Slide</td>
</tr>
<tr>
<td>3 5 m - &lt;20 m</td>
<td>Deep Slide</td>
</tr>
<tr>
<td>4 &gt;20 m</td>
<td>Very Deep Slide</td>
</tr>
</tbody>
</table>

Table 1.8: Classification of Landslides on the basis of its magnitude *(after USSR State Committee on Construction, 1981)*

<table>
<thead>
<tr>
<th>Scale of Landslides and Mudflows</th>
<th>Volume of Landslides and Mudflows in m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Small</td>
<td>Hundreds</td>
</tr>
<tr>
<td>2 Fairly Large</td>
<td>Thousands</td>
</tr>
<tr>
<td>3 Large</td>
<td>Tens of thousands</td>
</tr>
<tr>
<td>4 Very Large</td>
<td>Hundreds of thousands</td>
</tr>
<tr>
<td>5 Enormous</td>
<td>Millions</td>
</tr>
<tr>
<td>6 Colossal</td>
<td>Tens and hundreds of millions</td>
</tr>
</tbody>
</table>

Fig. 1.19: Field example of a fast moving landslide / rock fall
Table 1.9: A brief list of landslide causal factors

<table>
<thead>
<tr>
<th>A</th>
<th>GROUND CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plastic weak material</td>
</tr>
<tr>
<td></td>
<td>Sensitive material</td>
</tr>
<tr>
<td></td>
<td>Collapsible material</td>
</tr>
<tr>
<td></td>
<td>Weathered material</td>
</tr>
<tr>
<td></td>
<td>Sheared material (Fig. 1.31)</td>
</tr>
<tr>
<td></td>
<td>Jointed or fissured material</td>
</tr>
<tr>
<td></td>
<td>Adversely oriented structural discontinuities including faults,</td>
</tr>
<tr>
<td></td>
<td>unconformities, flexural shears, sedimentary contacts (Figs. 1.29 &amp; 1.31)</td>
</tr>
<tr>
<td></td>
<td>Adversely oriented mass discontinuities (including bedding, schistosity, cleavage)</td>
</tr>
<tr>
<td></td>
<td>Contrasts in permeability and its effects on ground water (Figs. 1.26 &amp; 1.27)</td>
</tr>
<tr>
<td></td>
<td>Contrasts in stiffness (stiff, dense material over plastic material)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B</th>
<th>GEOMORPHOLOGICAL PROCESSES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tectonic uplift</td>
</tr>
<tr>
<td></td>
<td>Volcanic uplift</td>
</tr>
<tr>
<td></td>
<td>Glacial Rebound</td>
</tr>
<tr>
<td></td>
<td>Fluvial erosion of the slope toe</td>
</tr>
<tr>
<td></td>
<td>Wave erosion of the slope toe</td>
</tr>
<tr>
<td></td>
<td>Glacial erosion of the slope toe</td>
</tr>
<tr>
<td></td>
<td>Erosion of the lateral margin</td>
</tr>
<tr>
<td></td>
<td>Subterranean erosion (solution, piping)</td>
</tr>
<tr>
<td></td>
<td>Deposition loading of slope at its crest</td>
</tr>
<tr>
<td></td>
<td>Vegetation removal (by erosion, forest fire, drought)</td>
</tr>
<tr>
<td></td>
<td>Ground Cracks (Fig. 1.30)</td>
</tr>
<tr>
<td></td>
<td>Subsidence (Fig. 1.49)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C</th>
<th>PHYSICAL PROCESSES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intense rainfall over a short period</td>
</tr>
<tr>
<td></td>
<td>Rapid melt of deep snow</td>
</tr>
<tr>
<td></td>
<td>Prolonged heavy precipitation</td>
</tr>
<tr>
<td></td>
<td>Rapid drawdown following floods, high tides or breaching of natural dam (Fig. 1.22)</td>
</tr>
</tbody>
</table>
• Earthquake
• Volcanic eruption
• Breaching of crater lake
• Thawing of permafrost
• Freeze and thaw weathering
• Shrink and swell weathering of expansive soils

D MAN-MADE PROCESSES
• Excavation of the slope or its toe
• Loading of the slope or its crest
• Drawdown of reservoir (Fig.1.22)
• Irrigation (Fig.1.23)
• Defective maintenance of drainage system (Fig.1.24)
• Water leakage from services like water supplies, sewage, storm water drains (Fig.1.25)
• Vegetation removal (deforestation)
• Mining and quarrying in open pits or underground galleries (Fig.1.21)
• Creation of dumps of very loose waste
• Artificial vibration including traffic, pile driving, heavy machinery, blasting and explosion (Fig.1.20)
• Poor maintenance of remedial measures (Figs.1.60 & 1.61)

1.6 Classification of Conditions/Factors responsible for Landslides

Some slopes are susceptible to landslides whereas others are not so. Many factors contribute to the instability of slopes but the main factors indicating stability conditions are relief, drainage, bedrock, regolith, vegetation, climate, earthquake, paleo-features and man-made conditions. The conditions/factors governing landslides can be classified as inherent (terrain) and external factors as given below.

1.6.1 Inherent or basic conditions

Geology
  Lithology
  Structure

Hydrologic conditions and climate
Vegetation
1.6.2 External Factors/conditions include precipitation, vibrations induced by earthquake / blasting / explosion, loading or unloading of slopes etc.

These factors may actually produce two different types of changes, i.e. changes in stress conditions and changes in strength of materials. The different factors producing different changes are given below for illustration.

1.6.3 Factors producing unfavorable changes in conditions

Those that change stress conditions

- Erosion or deposition
- Fluctuation in water level
- Seismic vibrations
- Construction activity
- Cuttings
- Reservoir fluctuations
- Landuse practices

Those that change strength of materials

- Progressive softening of fissured clays
- Disintegration of granular rocks (freeze & thaw)
- Hydration of clay minerals
- Drying and cracking of clays
- Loss of cementitious material from coherent material by solution

1.6.4 Landslide’s Driving Force

The principal driving force for any landslide is the gravitational force and the tendency to move of this mass will be proportional to the hill slope angle. The resisting forces preventing the mass from sliding down the slope are inversely proportional to the same hill slope angle and proportional to the friction angle of the material. Stability of the material resting on a slope will be reduced with an increased slope angle. In addition, the resisting forces can be significantly reduced in case of rain or earthquake vibrations.

1.7 Identifying Landslide Areas - The identification and prediction of a landslide is essential to minimize or control the hazard. Usually this is done using costly procedures as surveying, monitoring or soil testing, which are not affordable or feasible in rural regions with almost no resources. Therefore, simpler but still effective methods have to be used to assess the stability of slopes and decide if a given location is safe for construction. The following features may be used to identify probable landslide prone areas.
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- Existing or old landslides or places of historic landslides
- Areas at the base of slopes
- Within or at the base of minor drainage hollows
- At the base or top of a fill slope
- At the base or top of a cut slope
- Any sloping ground in an area known to have a landslide problem
- V-shaped valleys, canyon bottoms, and steep stream channels
- Fan shaped areas of sediments and boulders accumulation at the outlet of canyons
- Areas with large boulders (2 to 20 feet diameter) perched on soil near fans or adjacent to creeks
- Steep hill slopes above a home or hamlet
- Logjams in streams above a home or hamlet
- Steepened road cuts, sunken or down-dropped road beds
- Areas that have been extensively disturbed by excavation into steep slopes
- Moderately steep slopes that are exposed to high water flow
- Burn areas, intensively irrigated agricultural field, canyon, hillside, mountain and other steep areas are vulnerable to landslides

1.8 Potential landslide risk indicators - The following simple observations and inspection by community, municipal officials and property owners, may assist in assessing potential landslide hazards. It is important to note that some of these features can also be due to causes other than landslides, such as swelling clays.

- Saturated ground or seeps in areas that are not typically wet
- New cracks and scarps or unusual bulges in the ground, roads or pavements (Fig.1.36)
- Movement of ancillary structures such as decks and patios in relation to a house (Fig.1.42)
- Sticking doors and windows, and visible open spaces indicating jambs and frames out of plumb (Figs.1.32, 1.33, 1.34 & 1.37)
- Soil moving away from foundations
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls or fences
Landslides Introduction

- Offset fence lines or retaining walls (Fig.1.28)
- Sunken or displaced road surfaces (Fig.1.49)
- Rapid increase in creek water levels, possibly accompanied by increase in turbidity (soil content)
- Sudden decrease in creek water levels though rain is still pouring or just recently stopped
- Springs, seeps or saturated ground in areas that are not typically wet
- Thorough cracks in walls, gaps between roof and wall etc. (Fig.1.33 & 1.35)
- Damage to building elements (Fig.1.38)

In most cases in the field, one may find the presence of combination of landslide risk indicators.

It is important that local bodies provide a means of keeping records, preferably in written format, about the occurrence of landslides, with photographs and/or diagrams where-ever possible. This will provide a means to sustain landslide knowledge through time and it is important that such landslide information be made available, in some manner, to general public.

1.9 Effects and Consequences of Landslides

Landslide effects can be classified as direct and/or indirect.

Direct effects - are those first order consequences which occur immediately after an event, such as deaths and damage caused by landslides directly.

Indirect effects - may emerge after the landslide event and may be much less easy to attribute directly to landslides. This includes psycho-social impacts, bereavement and evacuation.

Similarly the effects may be classified as tangible and/or intangible.

Tangible effects - are those to which it is possible to assign reasonable reliable monetary values, such as replacement of a damaged property.

Intangible - can not be satisfactorily assessed in monetary terms; for example, loss of human life, has proved difficult to assess financially.

Landslides effects occur in 2 basic environments - built environment and the natural environment. Sometimes there is intersection between the two; for example agricultural lands and forest lands that are logged.

- Physical Injuries and Loss of human lives.
- Property / Infrastructural damages and economic losses
- Affect a variety of resources like water supplies, fisheries, sewage disposal systems, forest, dams and reservoirs etc.
1.9.1 Effects of Landslides on Built Environment

Landslides affect manmade structures whether these are directly on or near a landslide. Residential buildings on unstable slopes may experience partial damage to complete destruction as landslides destabilize or destroy foundations, walls, floors, surrounding property, utilities such as water pipelines, power lines, communication lines, transport routes etc. Commercial structures may also face similar consequences as the residential buildings but the consequences may be greater due to disruption in business due to damage of access routes.

Fast moving landslide such as debris flows and rock falls/topples are more destructive and life-taking as they often occur without precursors or warnings, move too quickly for any safety measures to be taken, with high momentum due its mass and velocity that can destroy anything that comes in its way; whereas slow moving landslide may only cause slight damage and its slow pace may allow implementation of mitigation measures as well. However, left unchecked, even slow landslides can completely destroy the structures over time (USGS Circular 1325). The nature of landslide movement and the fact that they may continue after days, weeks, or months preclude rebuilding on the affected area, unless mitigation measures are taken appropriately.

As the world population grows, they are increasingly vulnerable to landslides. People tend move on to new lands that might have been deemed too hazardous in the past but are now the only areas that remain for the growing population. Poor or non-existent landuse policies allow building and other constructions to take place on the land that might better be left to agriculture, parks or other such uses. Communities are not geareded to regulate unsafe buildings practices and may not have legitimate or adequate means / expertise to do so,

1.9.2 Impacts on buildings (including residential, commercial, private, public and government)

Landslides result in development of cracks in the buildings in case of slow moving / creeping landslides but may cause collapse or complete damage / burial of buildings in cases of sudden massive and fast moving landslides (Figs.1.38, 1.45 & 1.47). Figure 1.62 depicts the impact of Varunawat Landslide in Uttarkashi City of Garhwal Himalaya, Uttarakhand State, where nearly 400 houses were affected by the massive landslide.
One of the greatest consequences of landslides is its impacts on transportation system (roads and railways) which indirectly affects large number of people in any locality (Figs.1.39, 1.40, 1.48, 1.49, 1.51, 1.54, 1.58 & 1.59). Blockages of highways by landslides occur very commonly around the world, and many can simply be cleared by bull dozer or shoveled away. Others may require temporary diversion of traffic or even closure of road traffic or a major excavation. National / State highways and connecting roads are also very vulnerable to the impacts of landslides. A large number of landslide that occur along the roads and highway result in damage / destruction of transportation / access routes as well as pose risk to the vehicles and passengers / passers-by on the road-side. Figure 1.48 depicts the destruction of national highway to Badrinath due to Lambagar Landslide in Uttarakhand state and Figure 1.40 show the impacts of a rock-fall on a bus parked close to a landslide spot near Sukhi on Bhatwari-Gangotri National Highway in Uttarkashi district, Uttarakhand state.

1.9.4 Impact on essential services like power, communication, water supply etc.

Besides the buildings and roads, the landslide affect our essential services like power, communication and water supply etc. Particularly the rigid pipelines and structures are more badly affected compared to flexible / elastic pipes and structures. The photograph (a) below shows the inundation of a power tunnel in
a hydel project (Sanjay Jal Vidyut Yozna in Satluj Valley) due to blockade of river by a landslide on the downstream side, thus, hindering the operations for power generation. The photograph (b) reveals the problems of power transmission due to their location just close to the crown of retrogressive landslide, thereby endangering its stability and functionality.

1.9.5 Impacts on health and education sectors

Entire population in landslide prone areas is at risk; the most vulnerable are patients, pregnant ladies, and school children, especially the young ones. In a devastating landslide incidence of 18 August 2011 in Uttarakhand state, 18 school children aged between 5 and 11 years, were buried alive while attending the school. Similarly, there were instances when hospital buildings at Shimla and Rampur in Himachal Pradesh were damaged by the landslides. Thus, safety from landslides in educational and health buildings has prime importance as the people in them are dependent on others.

1.9.6 Effects on natural environment

Landslides may have the following impacts on natural environment

- The morphology of earth’s surface - mountain valley system, both on continents and beneath oceans, are most significantly affected by landslide due to morphological changes
- The forest and grassland cover changes
- The native wildlife, its rivers, lakes and seas.

The following landslides may occur in natural environment.

(a) Submarine Landslide is general term used to describe downslope mass movement of geologic materials from shallower to deeper regions of the oceans. Such events may produce major effects to the depth of shorelines. These types of landslide can occur in rivers, lakes and oceans. Large submarine landslides triggered by every intense arthquakes can cause deadly tsunamis.

(b) Coastal cliff retreat or cliff erosion - Falling rocks from eroding cliffs can be especially dangerous to anyone occupying areas at the base of cliffs, or on the beaches near cliffs. Large amount of landslide material can also be destructive to aquatic life such as fish.

(c) Landslide dams can naturally occur when a large landslide blocks the flow of river, causing a lake to form behind the blockage. Most
of these dams are short-lived as the water will eventually erode the dam. If the dam is not destroyed, it creates a lake. Lakes created by landslide dams can last a long time, or they may suddenly be released and cause massive flooding downstream.

### 1.9.7 Impacts on natural resources and cultural heritage

During Varunawat landslide at Uttarkashi, more than 300 pine trees got uprooted and about 300 trees were cut for treating the landslide. Besides the pine trees, numerous other varieties of trees and shrubs were also affected. Therefore, it can be surmised that a huge loss to the natural resources occur due to such landslides. Figures 1.56 and 1.57 depict the impacts of landslides at heritage structures in Uttarakhand.

### 1.9.8 Strategic Impact on National / Border Security

The occurrence of landslide can lead to security problems if it happens and blocks roads in international border areas. The movement of army vehicles and troupes on the ground can get hurdled by the landslides (Fig.1.43). The photograph below is depicting the situation of army movement when a landslide happened on a border road to Bhaironghati in Uttarakhand state. The insurgency by terrorists and anti-social elements also rises when the army movement is restrained by landslides in border areas.

### 1.9.9 Economic effects of landslides

- Cost of repair.
- Loss of property value
- Disruption of transportation routes
- Medical costs (injury)
- Water availability, quality and quantity

Direct Losses - are the most visible consequences of landslides. They may be comparatively easy to measure but they are not always the most significant outcome. They are caused by the immediate damage done to humans, resources and environment.

Indirect Losses - rise mainly through the second order consequences of landslides, such as disruption of economic and social activities in a community or onset of ill-health amongst disaster victims. These effects often outlast those of direct losses by months or even years and can be highly intangible.
1.10 Inter-relationship of landslides with other natural hazards

The Multiple Hazard Effect

Natural Hazards such as floods, earthquakes, volcanic eruptions and the landslides can occur simultaneously, or one or more of these hazards can trigger one or more of the others. Landslides are often the result of earthquakes, floods, and volcanic activity and may in turn cause subsequent hazards; for example an earthquake induced landslide can cause a deadly tsunami if sufficient landslide material goes into a body of water to displace a large volume of water. Another example would be a volcanic eruption induced or earthquake induced landslide that blocks a river, causing water to back up behind the mass and flood the upstream area. Should the dam fail, the impounded water will be suddenly unleashed to cause flooding downstream. The flooding can then add to riverbank and coastal erosion and destabilization through rapid saturation of slopes and undercutting of cliffs and banks. It is therefore, imperative, when evaluating an area’s vulnerability to landslides, to examine all other possible hazards. Thus, a multiple hazard susceptibility should be produced for showing all multi-hazard events involving landslides.

1.11 Communicating Landslide Hazard

The successful translation of natural hazard information into a form useful for non-technical users conveys the following 3 elements in one form or another.

- Likelihood of the occurrence of an event of a size and in a location that would cause casualties, damage, or disruption to an existing standard of safety
- Expected location and extent of the effects of the event on the ground, structures or socio-economic activity
- Estimated severity of the effects on the ground, structures or socio-economic activity

The non-technical user must be able to perceive likelihood, location and severity of the hazard so that they become aware of the danger, can convey the risk to others, and can use the translated information directly to reduce the risk.

1.12 Landslide Warning Signs

Some simple warning signs can be placed in hazardous areas along with some information that can be used in emergency management. Some basic information about safety tips for landslide prone areas may be posted and distributed among the public in such places.
1.13 Minimizing the effects of Landslides

Planners and Decision Makers should learn from past tragic events and should impose stringent planning and design requirements in landslide-prone and unstable areas. These may include:

- Implementation of regional hazard and risk assessments into land planning policies. This ensures that appropriate processes are in place whereby new development applications are assessed with respect to slope stability issues and zoning for future development is directed towards areas with a low or very low risk of slope instability.

- Engineering and geotechnical investigation that define the landslide hazard and risk at site specific levels of investigation.

- Mapping of landslide vulnerability that can help with the development of emergency response scenarios.

The following photographs exhibit some of the above features noticed in the field.
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Fig. 1.20: Blasting in road construction leads to landslides

Fig. 1.21: Improper open cast mining causes landslides

Fig. 1.22: Sudden and fast drawdown results in subsidence / landslides

Fig. 1.23: Inappropriate irrigation practices cause slope stability problems

Fig. 1.24: Ill-maintenance and clogging of drainage culverts results in damages

Fig. 1.25: Rigid pipelines and joints get ruptured during landslide and water leakage further aggravates the instability
Fig. 1.26: Seepage and leaching at junction between sand & clay beds

Fig. 1.27: Permeabilities contrasts in rocks leads to percolation and development of pore pressures

Fig. 1.28: Retaining walls get de-aligned due to landsliding

Fig. 1.29: Faults are weak zones susceptible to landsliding

Fig. 1.30: Ground cracks indicating incipient slope failures

Fig. 1.31: Fold axis is the weakest plane along which movement can occur
Fig. 1.32: Landslides create gap between door frame and floor

Fig. 1.33: Opening between wall and roof due to differential settlement

Fig. 1.34: Cracks appear close to doors and windows in a building

Fig. 1.35: Monitoring wall cracks using paper slips with markings

Fig. 1.36: Cracks appear in pavement / ground in a house

Fig. 1.37: Cracks extend from floor to walls during landslides
Fig. 1.38: Building gets damaged posing risk to residents

Fig. 1.39: Extensive damages to roads from landsliding

Fig. 1.40: Bus damaged due to boulder fall; it was parked close to slide spot

Fig. 1.41: Stability of towers affected due to its proximity with slide

Fig. 1.42: Differential settlement in pavement / floors in houses

Fig. 1.43: Army personnel facing problems of access after a landslide on a border road
Fig. 1.44: Transit lake created due to river damming by landslide

Fig. 1.45: Residents protect houses by using polythene sheets to prevent seepage

Fig. 1.46: Tunnel in a hydel project filled with muddy water after a landslide dam on a river

Fig. 1.47: Earthquake induced landslide causing damages to a cluster of houses

Fig. 1.48: Complete road washed off after bursting of transient landslide dam

Fig. 1.49: Subsidence causing differential settlement and damage to road
Fig. 1.50: Petrol pump damaged leading to fuel shortage

Fig. 1.51: Bridge washed off due to landsliding

Fig. 1.52: Landslide affects cluster of houses at foothill slopes

Fig. 1.53: Post-earthquake landslide affects UNESCO heritage toy train track adversely

Fig. 1.54: Landslide causes damage to railway track and road

Fig. 1.55: Net barriers to reduce the impacts of debris flow, need proper maintenance
Fig. 1.56: Heritage building at risk from landslides

Fig. 1.57: Historical pilgrimage sites at risk from landslides

Fig. 1.58: Passengers and traffic stranded due to landslides

Fig. 1.59: Railway track damaged due to landslides

Fig. 1.60: Ill-maintained culverts get damaged and cracked

Fig. 1.61: Poor maintenance of mitigation measures causes failures
2.1 Landslide Inventory

The main purpose of preparation of a landslide inventory map and database is documentation of all the known landslide incidences including stabilized, dormant, reactivated and most recent slides. The documentation includes location, date of occurrence, triggering factors like rainfall and seismicity during the event, dimension and type of slide, volume of material dislodged, nature and extent of damages caused/may be caused by further sliding, type of triggering factor (earthquake, cloudburst, anthropogenic interference, toe erosion by streams or rivers etc.), probable causes and run-out distance. A colour photograph and sketch plan of the landslide on the date of investigation will be an additional input. Another important parameter is the collection of historical record of each slide which will give an idea about the approximate return period of the slide. All such information paves the foundation for LHZ mapping, vulnerability assessment and risk zonation mapping.

A landslide inventory map not only shows the time and date of occurrence but approaches, ranging from digital stereo image interpretation to automatic classification based either on spectral or altitude differences, or a combination of both. The multi temporal images can be used to prepare a landslide activity map. The stereo-images are not only useful for the derivation of height information but also for landslide inventory mapping as it provides a 3-dimensional visualisation opportunity.

Very high resolution imaging technique (QuickBird, IKONOS, CARTOSAT-1 and 2) has become the best option now for landslide mapping through remote sensing, and the number of operational sensors with similar characteristics is growing year by year. Other remote sensing approaches of landslide inventory mapping include shaded relief images produced from Light Detection and Ranging (LiDAR) DEM and Synthetic Aperture Radar (SAR) interferometry. Lidar is an active sensor and the signal from the sensor from onboard aircraft has the capability in most case, of penetrating the tree crowns and thus provides data about subtle elevation variation of the bare ground. Lidar data has been used to prepare landslide inventory in forest areas in hilly regions and to refine the
boundaries of landslides marked during field investigations. This data is not only useful for mapping old landslides but also is a tool to improve field survey based investigation in regions with subdued morphology. SAR images are useful in identifying critical terrain elements such as faults and slope characteristics. Also subtle movement due to landslides can be picked up from interferograms generated from SAR image pairs. Another advantage of SAR over optical sensor is its all weather monitoring ability. So, combination of SAR imagery with high resolution optical multispectral imagery is useful for monitoring debris hazard in mountainous areas. However the problems such as foreshortening and layover effects associated with SAR data in mountainous areas have to be addressed carefully.

Preparation of a comprehensive and user-friendly national landslide inventory database will be taken up, thus paving way for continuous updating of the landslide map of India. This will be achieved by nation-wide networking of the agencies engaged in the task and would be aided by the latest tools of geomatics and followed by field checks.

2.2 Landslide Database

A. Location of the Slide Site
   i. Name of Road
   ii. Motorable Road or bridle road
   iii. Nearest village or town and direction and distance of the slide from it
   iv. Slide developed at km (From ---- to ----- )

B. General Description of the Area
   i. Elevation (Height above M.S.L.)
   ii. Slope on Uphill side
   iii. Slope on downhill side
   iv. State of erosion on slope
   v. Density of vegetation (low, medium, high); give details of trees and vegetation.
   vi. Are trees tilted?
   vii. Are there cultivated fields?
   viii. Monthly data for average rainfall for last 3 years. Annual rainfall for last 10 years or as many years as available.
   ix. Name of the nearest observatory.
C. **Geological Features of the Area**
   
i. Type of rock exposed or below the ground (thinly/thickly bedded or massive).
   
ii. Dip and strike
   
   
iv. Structural features (folds, faults, conformity)
   
v. Stratigraphic position.
   
vi. Lithological characteristics of the rock with sequence of formation
   
vii. Texture of rocks
   
viii. If not rocky to which following types it belongs:
       Debris (soil to rock pieces)
       Soil (almost no rock pieces)

D. **Drainage Features**
   
i. Is there any nala or river flowing at toe of the slide, if so indicate whether it was eroding the toe of the slope.
   
ii. Give the position of water accumulation, place of spring water, position of snow accumulation with respect to position of road.
   
iii. Is any water body (pond or lake) present on hill slope?
   
iv. Any other remark regarding nature of hill slope affecting the stability of hill slope.

E. **History & Description of the Slide during its Development**
   
   a. **Sketch of the Slide**
      
      (Please sketch the slide showing its relationship with road and/or other landmarks, take photographs from appropriate angles and sufficient in number to be able to generate a panoramic view of the area by making mosaic photographs.

      The sketch should show approximate dimensions, boundaries of the slide, position of notable cracks, position of the road, nala and river if any, water path, places of water percolation, spring water, position of road outcrops, big boulders, trees, retaining walls and other prominent structures, position of sinking areas, if any.

   i. Date of Occurrence of slide.
   
   ii. Number of times the slide has taken place in the known past
iii. Duration of the road blockage due to slide
iv. Number of casualties or persons injured, if any.
v. Damages to the property due to slide (houses, road, fields etc.)
   a. Number of houses completely damaged
   b. Number of houses partially damaged
   c. Number of livestock lost
d. Nature of Damage
e. Occurrence of damage
f. Progressive nature of damage - Yes/No
g. If extension of damage has any relation with season - Yes/No
h. If yes, whom and how observed and their details.
i. Period of extension of damage.

vi. Method of clearance of slide mass by manually/by machine or by both.
vii. Time taken for clearance.
viii. Condition before occurrence of slide (dry, heavy rains etc.)
ix. Was road sinking noticed?
x. Slope angle.
xi. Height of crown of the slide from road level.
 xii. Depth of toe of the slide from road level
xiii. Any other remarkable point observed during or before slide.
xiv. Rate of movement (cm per day)

F. Causes of Slide
   i. Whether it was human action (such as back cutting, blasting, excavation, changes in nature / artificial drainage etc.)
   ii. Natural cause (such as river erosion, nala erosion, saturation of hill slope mass, cloud burst, unfavourable nature of hill slope mass, earthquake, deforestation, disruption of drainage etc.)
   iii. Any other cause visualized at the site.

Note: Generally more than one cause develop the slide but one cause may be dominant

G. Remedial Measures
   i. Whether applied - Yes/No. If yes, please state the measures, viz.:
a. Sealing of cracks.
b. Provision of retaining structures.
c. Improvement in drainage.
d. Measures for protecting river erosion
e. Chemical treatment
f. Grouting
g. Plantation etc.

*What is their outcome?*

ii. Has the slide area been studied for adopting remedial measures by any competent investigator? If so, give the name of organisation and the summary of major recommendations.

iii. Indicate what measures were followed and their outcome.

**H. Notes:**

i. Please complete separate sheet for important slide site of your region. Mark the location of all slides of your region on the district map.

ii. Your active input of the information is required and will help the investigator in suggesting corrective measures to pertinent landslides and similar ones.

iii. If you feel problem in providing information, the respective column may be left blank, but should be followed up later. Some of the information as e.g. in para (3) may be left for geologist, in case the field engineers are not able to fill it.

Date:-------------------------  
Signature (Name) of Reporting Officer  
Designation

### 2.3 Landslide Hazard Zonation Mapping

The aim of LHZ, a pre-requisite for risk assessment, is to determine spatial and temporal extent of landslide hazard. In general the LHZ map divides the landslide prone hilly terrain into different zones according to their relative degree of susceptibility to landslides. It requires identification of those areas that are, or could be, affected by landslides and assessing the probability of such landslides occurring within a specific period of time. Commenting on the time domain of landslide occurrences through zonation mapping is a difficult
task. Due to conceptual and operational limitations, landslide hazard zonation is conceptually stated as landslide susceptibility zonation (LSZ). Spatial prediction of landslide is termed as landslide susceptibility, which is a function of landslide and landslide related internal factors (i.e., ground characteristics). The aim is to identify places of landslide occurrence over a region on the basis of a set of physical parameters. The LSZ can formally be defined as the division of land surface into near-homogeneous zones and then ranking these according to the degrees of actual or potential hazard due to landslides. The LSZ maps do not directly incorporate time and magnitude of landslide occurrences. Since LSZ is conceptually accepted as LHZ, it is popularly used as LHZ all over India. A Landslide Risk Zonation Map integrates landslide hazard, landslide vulnerability and degree of risk.

LHZ map requires dividing an area into several zones indicating progressive levels of landslide hazard. The number of zones into which the territory is divided is generally arbitrary. Landslide hazard zoning entails mapping all possible landslides and landslide-induced hazards to the required detail. The hazard maps are designed to limit information to the users’ requirements, and present it in a form comprehensible to them. Indeed, the users’ maps ought to be different from those prepared by or for specialists. Graded landslide hazard maps are required by, among others, developmental planners as tools for efficient management of land and its resources. Landslide hazard maps are also essential for assessment of damage potential, and for quantification of risks. Scientific forecasting of a landslide for early warning finds its first clue in the landslide hazard map of the area.

It is necessary to understand the conditions and processes that control landslides and determine existing landslide hazard if future landslide occurrences are to be estimated. A map of existing landslides serves as the basic data resource for understanding these conditions and processes. Existing landslides and their relationship with other key parameters - nature of slope forming material, slope inclination and aspect, land cover, landuse, climate and hydrology - form the basis for hazard assessment.

An all-inclusive approach for mapping slides, starting with the assessment of regional geologic and geomorphic setting, then focusing on detailed scale is recommended. A comprehensive view of the terrain is needed to identify all possible problems associated with slope condition, including existing and potential instability. It is necessary to review the impact of geological features located beyond the boundaries of the site that could influence the status of hazard in future. There may be vital evidence of instability processes outside
the area to be developed that may not be evident on the site itself, but could have a future impact on the site.

The available geological and geomorphological maps form the basic inputs for LHZ mapping. It is not at all possible to prepare all thematic maps covering vast areas by field work. This problem can be solved with the help of aerial photographs or satellite imageries followed by limited field checks.

Preparation of maps showing landslide hazard includes:

- Generation of thematic maps by compiling and collating the observations on geology, geomorphology, landuse, land cover and distribution of landslide processes including use of local records, interpretation of aerial photographs and high-resolution imageries.
- Collection of relevant information on the existing landslide hazard and analysis of potential landslide hazard including first times.
- Identification of areas that could be affected by landslide hazard in future.
- Transformation of process maps into hazard maps identifying the potential for spatial impact and probability of occurrence of hazard.

2.4 Selection of Scales

Landslides related data and information have to be mapped on a scale that is suitable for end-use purposes to enable planners to make decisions about future landuse on or close to landslides or landslide-affected areas. At present, only a few local authorities have access to landslide maps on appropriate planning-level scale (say 1:10,000). Most of them are ignorant even about 1:50,000 scale maps. While these or smaller scale maps are appropriate for regional studies, they do not provide adequate detail for planning at local level which requires detailed information at least up to municipal ward level. At present, very little area of the country has been mapped even on 1:50,000 or 1:25,000 scales on the landslide theme. It is important that a landslide hazard map be on a scale not markedly different from the data maps used to produce it otherwise estimation of hazard might be misleading.

Considering the importance of landslide hazard and its mapping, GoI constituted a Task Force on LHZ Mapping in March 1999. Keeping in view the availability of topographic and geological maps in the country at present and recommendations of the Task Force, different scales suggested for preparation of LHZ maps for different purposes are given below.
MAP SCALE FOR LANDSLIDES
- National or Regional (1:100,000 to 1:1,000,000)
- Macro- scales (1:25,000 to 1:50,000) - River basins, communication routes etc.
- Meso-scales (1:5,000 to 1:10,000) municipalities, localities etc.
- Mapping on scales larger than those on meso- scales should be carried out for site-specific studies and not for zonation.

However, it is not appropriate to carry out zonation on scales larger than 1:5000. Landslide studies are being carried out on 1:5000 and larger scales for detailed studies. A nation-wide consensus on the rationale of selection of uniform mapping scales should be developed.

Figur 2.1 Landslide Hazard Zonation Map of India (source: GSI)

2.5 Seismic Landslide Hazard Zonation

The principal triggers for landslides are rainfall, earthquake and anthropogenic activities. Since landslides in most areas can co-occur with other hazardous events like earthquakes, intense rainfall or cloudburst, these areas can suffer from more than one hazard at a time. Therefore, it is required that risk emanating from all hazards should be considered for assessing the total risk. It implies that it is necessary to integrate the landslide hazard into multi hazard concept.
The landslides triggered or induced by earthquakes are known as co-seismic landslides. Earthquake triggered slides occur when existing landslides are activated by an earthquake and earthquake induced are fresh or first time generated slides caused by an earthquake. Earthquake induced first time landslides are few but earthquake-triggered landslides are many. In a great majority of cases, landslides take place with the earthquake shock, and a few of them may also occur hours and days after the shock. It is observed that the extent of the area within which landsliding is generated tends to increase with the shock magnitude. Seismically generated landslides occur suddenly and in more widespread area. Example: Eastern Nepal – Sikkim earthquake (M-6.9 on Richter Scale, 18 September 2011) induced widespread landslides in Sikkim, West Bengal, Bihar and Nepal.

The most abundant types of earthquake-induced landslides are rock falls and slides of the slope forming material resting on steep slopes. However, almost every other type of landslide can occur due to an earthquake but landslides resulting from liquefaction are caused by a seismic event only. Other types of mass movements that can be generally related with seismic activity are:

- Rock avalanches on over-steepened slopes in weak rocks
- Mud flows, rapidly moving wet earth flows that can be initiated by earthquake shaking

Comprehensive research, development and field oriented studies on instrumented problematic slopes would be undertaken to improve our understanding of earthquake induced landslides. Multi-hazard and seismic micro-zonation programmes will be enriched by added focus on hither to neglected subject of earthquake induced site affected in hilly areas and their effect on slope instability.

### 2.6 Earthquake-Induced Landslides

A clear distinction is essential between the earthquake-triggered and earthquake induced landslides. Earthquake events are usually known to serve as a trigger for pre existing but dormant landslides to create what may be called as earthquake-triggered landslides. Strong tremors, however, hold the potential to induce new slides especially by rupture along unfavorable discontinuities and shear zones. Such slides are designated as earthquake-induced landslides. It should also be recognized that the commonest classes of the best-understood problems are flow slides due to liquefaction. The other possibilities are (a) reactivation of old, dormant or previously inactive landslides (b) acceleration of known landslides (c) triggering of rock falls (d) development of fresh, first time landslides, and
(e) onset of slumping and breaking up of the ground. The understanding of whole process presupposes understanding of (a) topographic and hydrological controls, (b) geological and geotechnical controls (c) seismological controls and (d) anthropogenic controls.

- Ground surface acceleration alone is a poor measure of the effect of shaking on slope stability. Intensity is even more so. The indicators such as ground velocity, experiences on past earthquake events, and duration of shaking are considered to be better indicators of landslide susceptibility under seismic conditions. Critical acceleration of a slope is also an important factor in deciding seismic safety of a slope. The factor of safety during an earthquake may drop below one (limit equilibrium state) for a short time, but the effect of failure on the slope may perhaps be negligible, and needs to be determined.

- The observation that catastrophic landslide events are a post-seismic phenomena rather than a co-seismic happening needs to be investigated. While the earthquake provides the trigger, the development of a landslide is seldom sudden, and it usually occurs after the earthquake and its after-shocks.

2.7 Government Policies and Initiatives

- The devastating Malpa tragedy resulting from a landslide that occurred along Kailash- Mansarovar route in the Kumaon Himalayans in August 1998 acted as an eye-opener for the GoI as far as landslide hazard is concerned. It decided to set up 3 different Task Forces for LHZ; Geotechnical Investigations and landuse zonation and regulation. Geological Survey of India (GSI) was identified as the nodal agency for LHZ while Department of Science & Technology (DST) and Ministry of Environment & Forest (MoEF) were identified as nodal agencies for the other two Task Forces, respectively. Consequently, Department of Mines (DoM) constituted a Task Force for LHZ in order to review the existing methodologies for LHZ study; to prioritise areas/belts for LHZ study and to recommend a plan for preparation of macro/meso/micro LHZ maps. The report of the Task Force on LHZ was submitted to the Government in September 2000.

- There are many government departments and organizations engaged in landslide hazard studies and hazard management in the country. These include GSI, Central Road Research Institute (CRRI), Central Building Research Institute (CBRI), Indian Institute of Technology-Roorkee (IIT-R), Wadia Institute of Himalayan Geology (WIHG), Department of Space (DoS), National Remote Sensing Centre (NRSC), Defence Terrain Analysis
and Research Laboratory (DTRL), Bureau of Indian Standards (BIS), some academic institutions and individual experts to name a few. Snow and Avalanches Studies Establishment (SASE) under Ministry of Defence (MoD) is engaged in studying snow avalanches. In addition, Border Roads Organisation (BRO) is the principal agency responsible for construction and maintenance of roads in almost all hilly regions of the country and Department of Science and Technology (DST) has been funding the R&D activities that include different types of landslide investigations.

- The earliest works in the field of landslides in the country were carried out by the GSI. These include study of Nainital landslide by Sir R.D. Oldham in 1880 and C.S. Middlemiss in 1890, study of Gohana slide in 1893 in erstwhile UP Himalaya that resulted in formation of 350m high landslide dam across Birehiganga. Till date the Department has carried out studies on more than 1500 incidences of landslides. In case of LHZ mapping, GSI has prepared LHZ maps on 1:50,000/25,000 scale covering about 45,000 km² area in the landslide prone hilly tracts. Landslide Hazard Zonation has also been carried out on the same scale covering about 4000 line km along the important National & State Highways. Besides, GSI has also prepared detailed LHZ maps of around five landslide affected townships in different parts of the country on 1:5000/10,000.

- The facet based LHZ methodology was initiated at University of Roorkee, (now Indian Institute of Technology) in mid eighties and the work is still continuing over different parts of Uttarakhand Himalaya incorporating progressive improvements. Several workers and Institutes later adopted the facet based LHZ mapping.

- Major areas of activity of CRRI include geological and geotechnical investigations of landslides, landslide hazard potential and risk analysis, instrumentation, monitoring and prevention of landslides. CRRI has published reports on landslide correction techniques, application of geo-textiles, deep trench drains and promotion of jute based geo-textiles etc. CRRI has also prepared a partial database of over 200 landslides of different parts of the country.

- CBRI has prepared LHZ maps in parts of Garhwal (Uttarakhand), Sikkim and Darjeeling Himalaya (West Bengal) using different techniques; it has also carried out monitoring of some landslides. The Institute has also implemented the control measures at Mussoorie bye-pass and Kaliasaur landslides in the state of Uttarakhand.
Landslides Inventory And Hazard Zonation

- Central Scientific Instrumentation Organization (CSIO), a national Laboratory of instrumentation, has installed an instrumentation network for landslide monitoring at Mansa Devi, Haridwar in 2006.

- WIHG carried out LHZ mapping in parts of Satluj valley. The institution has also monitored a few landslides.

- BIS has the responsibility of developing zoning codes and guidelines related to landslide practices. It has issued guidelines related to LHZ mapping on macro-scales, construction of retaining walls and landslide controls. BIS is developing guidelines of LHZ mapping on meso and macro scale, risk evaluation, detailed investigations etc. so that standard practices are followed in landslide studies.

- Initial landslide hazard Atlas of India on small scale was jointly published by Building Materials Technology Promotion Council (BMTPC) and Anna University in 2004.

- NRSA had undertaken a specific project of preparation of landslide hazard Zonation (LHZ) maps on 1:25000 scale along various pilgrimage routes and important highways in Uttarakhand and Himachal Himalaya. Utilization of latest available remote sensing techniques and synthesisation of data on GIS platform were highlights of the work. The NRSA published two volumes (I&II) of Atlas on LHZ in 2004. The NRSA has also carried out high resolution aerial survey for Varunawat landslide and provided detail maps on the contour, slope etc. The NRSA, GSI and ITC are collaborating on developing landslide risk assessment model for NW & NE Himalayas and also Western Ghats. A collaborative project on LHZ for NH-17 (Mumbai to Goa) by the GSI and NRSA is in progress.

- With the availability of high resolution images, it is possible for the NRSA to monitor the slides through these techniques and also keep an eye on occurrence of new slides as well as on formation of landslide dams in highly inaccessible areas.

- National Institute of Disaster Management (NIDM), which works under the control of NDMA, has the capability to develop training modules, formulate and implement human resources development plans, organize training programmes covering disaster management of natural hazards including landslides, develop education material for disaster management and provide assistance to State Governments and State Training Institutes in formulation of State level policies and plans for disaster management.

- DST has been carrying out a number of activities related to Landslide Management for the past 15 years. It carried out landslide hazard mapping
in parts of Sutlej Valley in Himachal Pradesh, Kumaon and Garhwal areas in Uttarakhand, Konkan Railway Region from Panvel to Ratnagiri, Nilgiris and North-eastern States of Manipur, Nagaland, Mizoram, Sikkim and Arunachal Pradesh. The data/maps are in digital form and can be shared for DM activities. DST has also developed Software/Brochures for Land Slide Safe Route Finder to provide safe navigation while constructing new communication lines/roads in hilly areas.

- DST has brought out many publications on landsides and related issues like coordinated national programme on “Landslide Hazard Mitigation”; A field Manual for landslide investigations etc. It also periodically organizes awareness programmes / courses / workshops amongst the Government agencies / NGO and communities.

- In collaboration with International Centre for Geo-hazards and Norwegian Geo technical Institute, DST is establishing a National Geo-technical facility (NGF) in Dehradun. NGF aims to have the state-of-the-art in Geo-technical Sciences and provide platform for building capacities in Geo-technical investigations and research. This will also help in networking the institutions within the country which have facilities and technical man-power. It is expected that NGF will provide inputs for DM related activities in designing / retrofitting the under-ground / over-ground structures.

- Central Water Commission (CWC) has been a lead agency to assess the hazard potential of landslide dams in the country and its vicinity.

2.8 Measures to reduce landslides hazards and/or risks

If unacceptable levels of landslide safety are identified, it may be appropriate and necessary, that the professionals provide recommendations for measures to reduce landslide hazards and/or risks. Measures can be passive such as covenants or relocation of proposed buildings, or active such as stabilization or protective works. Residual risks, or those that remain should the recommendations be implemented, should be estimated and clearly explained.

Typically, a landslide assessment report should include the following:

- Legal description of the property
- Location map or description of property relative to well known geographic features
- Objectives, method of landslide hazard or landslide risk analysis, and the level of effort
• List of background information available, collected and reviewed, and its relevance
• Terrain or physical description of the study area
• Map or plan of the property including topography, natural features, existing structures, roads, infrastructure and surface drainage
• Description of proposed residential development
• Methods and intensity of field work
• Observations of topography, geology, landslide processes and elements at risk
• If applicable, adopted level of landslide safety used for comparison
• Results of landslide assessment
• Conclusions, accompanied by supporting rationale
• Recommendations, if requested and as required, to reduce the landslide hazards and/or risks
• An estimate of the associated residual risks if the recommendations are implemented
• If required, recommendations for further work and requirements for future inspections, and by whom
• Definitions of qualitative terms, technical terms, concepts and variables
• Other information as specified in the agreement with client, or as required jurisdictional guidelines
• References, including maps and photographs
• Limitations and qualifications of the assessment and report, assumptions, error limits and uncertainties

Reports should be accompanied by drawings, figures, sketches, photos, test reports/logs, tables and other supporting information/data. Graphic information should be consistent with the information in the text. Maps or plans should delineate the areas of landslide hazards and risks in relation to existing and proposed residential development. The report should be written clearly to allow reviewers to understand the methods, information used and supporting rationale for the conclusions and recommendations, without necessarily visiting the site. A peer review of landslide assessment report, prior to its submission to the client and/or authority, is strongly encouraged as part of quality assurance/control programme.
2.9 Limitations and Qualifications of Landslides Assessment

The limitations and qualifications of a landslide assessment depend on the objectives, method of landslide hazard or risk analysis, level of effort, size of the study area, stability and geological and geotechnical complexity of the terrain, type of residential development, elements at risk, availability, quality and reliability of background information and field data, intensity of field work, experience and local experience of the professional, and whether or not a defined level of landslide safety has been adopted by the approving authority.

Although field work associated with a landslide assessment can provide reasonable coverage of the study area, field work may not cover the entire study area or all areas potentially affected by residential development. The extent of field work should be described in the report.

Many aspects of landslide assessment are qualitative and subjective based on observed, inferred and assumed conditions. Only some landslide assessments include subsurface investigations, sampling, instrumentation, monitoring and laboratory testing.

Conclusions and recommendations are based on the assumption that standard methods of residential development will be followed. Non-standard development, design and/or constructions recommendations should be clearly described. Substandard practices of construction may render the conclusions and recommendations invalid and sometimes damaging.

The life of landslide assessment report depends on the occurrence of subsequent landslides, changes in landuse, site development, neglect or discovery of previously unknown information.

Limitations and qualifications, including those associated with background information, assumptions, sources of error and range of values, should be clearly described in the report.

Levels of landslide safety are determined by society, not individuals. Therefore, for residential development, the levels must be established and adopted by the local and provincial government after consideration of a range of societal values. For example, factor of safety of a slope under static conditions must be significantly greater than one to accommodate earthquake loads. Acceptable factor of safety depends on the uncertainty in the analysis, the soil parameters and the magnitude and duration of seismic excitation, in addition to the potential consequences of slope failure.
Fig 2.2 Map Showing Distribution of Failed Slopes in Dunda Uttarkashi

Fig 2.3 Drainage Map of the Dunda Uttarkashi Area
Fig 2.4 Geology Map of Dunda, Uttarkashi Area

Fig. 2.5 Slope Map of the Dunda, Uttarkashi Area
Fig. 2.6 Structure & Tectonic Map of the Dunda, Uttarkashi

Fig. 2.7 Landuse Map of Dunda, Uttarkashi
Fig. 2.8 Relative Relief Map of the Dunda, Uttarkashi

Fig. 2.9 Relative Slope Instability Zonation (RSIZ) Map of the Dunda, Uttarkashi
3.1 Introduction

Landslide is a natural process, which occurs and recurs in certain geologic settings under certain conditions. The rising costs of landslide damages are a direct consequence of the increasing vulnerability of the people, structures and resources to the hazard. The vulnerability of people to the natural hazard is determined by the relationship between the occurrence of extreme events, the proximity of people to these occurrences, and the degree to which the people are prepared to cope with these extremes of nature.

\[ Rt = (E) \times (Rs) = (E) \times (H \times V) \]

where \( Rt \) is Total Risk,
\( E \) - Elements at risk,
\( Rs \) - Specific Risk,
\( H \) - Natural Hazard,
\( V \) - Vulnerability

3.2 Principles

- The past and present are key to the future.
- The main conditions that cause landslide, can be identified.
- Degree of hazard can be estimated.

3.3 Landslide Risk Assessment

Natural hazard is a condition that expresses the probability of a damaging event occurring with a specified magnitude within a defined time period and area. Risk is a measure of the probability and severity of the damaging event.

Landslide risk can be defined as the potential for adverse consequences, loss, harm or detriment to population and resources. Hence, landslide risk is a combination of the probability of occurrence of landslides and the consequences due to landslides.

Management of risk involves the complete process of risk assessment and risk control. Risk assessment, the process of risk analysis and evaluation, is the initial and the most important step of risk management. Conducting a risk assessment can provide information on location of hazard, value of existing
Landslides Risk Treatment

land and property, an analysis of risk to life, property and the environment that may result from natural hazard events. The complete Risk Management process comprises three components:

- Risk analysis
- Risk evaluation, and
- Risk treatment

3.3.1 Risk Analysis: Risk analysis involves the use of available information to estimate the risk to individuals or populations, property or the environment from hazard. The effects of landslide may not be limited to property damage and injury/loss of life. Other consequences may include public outrage, political effects, and loss of business confidence, social upheaval and consequential costs, such as litigation. It is important to define the site, geographic limits that may be involved in the processes that affect the site, scope of analysis, the extent and nature of the investigations that will be carried out, types of analyses that will be conducted and basis for assessment of acceptable and tolerable risks. Subsequent to hazard identification, risk estimation must be carried out.

Risk estimation may be carried out quantitatively, semi quantitatively or qualitatively. Wherever possible, the Risk Estimate should be based on a quantitative analysis, even though the results may be summarized in a qualitative terminology.

A complete risk analysis involves consideration of all landslide hazards for the site (e.g. large, deep seated landslide, smaller slides, boulder falls, debris flows) and all elements at risk. For computation of total risk, the risk for each hazard for each element is summed up. Most of the approaches applied for assessing Landslides Risk Analysis have inherent limitations but the risk analysis has the benefit of encouraging a systematic approach to assessing the problem and promoting a greater understanding of consequences. The risk analysis, assessment and evaluation can be done through detailed analysis employing multi disciplinary approach. In this effort the geological and geotechnical investigations play an important role.

Landslide Risk Analysis (LRA) can be made at different stages in the decision-making process, starting from developmental planning on a regional scale to a particular site evaluation at large scale. Landslide risk assessment on a regional scale leads to demarcation of areas with different levels of threat to risk elements. This information can be used to establish landuse plans, developmental activities and patterns of building regulations. LRA on regional
scale depends on two factors: (i) the spatial probability of landslide occurrences in a region and (ii) the vulnerability of resources at risk.

The spatial probability of landslide occurrences depends on the causative factors. Hence, the LHZ maps may be used to define the landslide potential in a region.

Vulnerability may be defined as the level of potential damage, or degree of loss of resources at risk, subjected to a landslide occurrence of a given intensity. Vulnerability assessment involves the understanding of the interaction between a given landslide and the affected resources. Generally, the vulnerability to a particular landslide may depend on the volume and velocity of sliding, the distance of transported sliding material, the resources at risk, their nature and proximity to the landslide. The assessment of vulnerability is somewhat subjective and may largely be based on the historical data of the region. However, in case of a regional scale vulnerability assessment, the resources at risk and their nature and proximity to landslide hazard zones may be considered. The appropriate vulnerability factor may be assessed systematically based on the opinions of experts and can be expressed at a scale of 0 to 1.

In the present context of regional risk analysis on regional/macro/meso scales, the LRA can be considered as a function of landslide potential (LP) and resource damage potential (RDP). The LP and RDP can be characterized by LHZ map and resource map (i.e., landuse and land cover map) of the area respectively. The LRA map can be obtained by integrating landslide susceptibility and resource damage potential at spatial level. This map can be categorized into areas of different risk zones. Therefore, risk maps essentially include landslide hazard map and elements at risk map. Landslide hazard map is generated by the integration of thematic maps, landslide incidence maps and vulnerability maps.

For site specific LRA, run-out effect analysis due to specific landslides based on travel distance analysis method can be implemented.

In risk analysis, the role of remote sensing is of utmost importance in providing necessary inputs for identifying the element at risk. The large coverage of satellite data with its temporal capability is useful for mapping the landuse / land cover, infrastructure, settlements which are vital input for landslide risk assessments.

3.3.2 Risk Evaluation: Risk Evaluation is the final step in the Risk Assessment process. The main objectives of risk evaluation are usually to decide whether to accept or treat the risks and identify priorities. Risk evaluation involves
making judgments about the significance and acceptability of the estimated risk. Evaluation may involve comparison of the assessed risks with other risks or with risk acceptance criteria related to financial aspects, loss of life or other parameters. Risk evaluation may include consideration of issues such as environmental effects, politics, business or public confidence and reaction. While evaluating risk, it is important to distinguish between acceptable risk which society is prepared to face as such without considering its management and tolerable risk that they have confidence that it is being properly controlled and monitored. This applies to both property and loss of life.

3.4 Risk Assessment Framework

3.4.1 Sliding

What is the probability of sliding?
- Rain/snow/reservoir seepage induced
- Earthquake induced
- Earthquake induced liquefaction
- Reservoir drawdown induced
- Combination of the above

If landslide occurs, how large will it be?
- Which mechanisms induced sliding?
- How deep is the slide (i.e. surface of rupture)?
- How long along the river?
- How long normal to the river?

How far will the displaced material move?

What will be the reservoir level be?

What quantity of the displaced material will reach the reservoir and how quickly?

What will be volume of water displaced? Will it generate a wave?

What are the expected losses?

Will these be acceptable?

What is the probability of secondary movement? Subsequent landslide?

3.4.2 Rock Fall

Rockfall from cutting present several hazards to users:
- a. Moving highway traffic obstructed by rockfall
b. Stationary vehicle hit by rockfall
c. Moving vehicle hits a fallen rock
d. Rockfall could block traffic causing costly delays and diversion of traffic
e. Damage to highway
f. Pedestrians, cyclists, highway maintenance workers impacted by rockfall

What is the probability of rockfall?
How big will the rockfall be?
Where will be the impact of rockfall?
What is the number and characteristics of vehicles (speed and length of vehicle etc.) using the highway?
What is the probability of a moving vehicle being hit by a falling rock?
What is the probability of a stationary vehicle being hit by a falling rock?
What is the probability of a moving vehicle hitting a fallen rock?
In the event that a rock impacts a vehicle, what is the probability of fatality?
What are the acceptable risk criteria?

3.4.3 Debris Flows

The main hazard due to debris flow in a settlement area may cause:

a. Damage to houses in the debris flow path and its deposition
b. Damage to urban infrastructure, e.g. roads, power and telephone lines, and drainage
c. Potential for fatalities and injuries to persons in the houses
d. Potential for fatalities and injury to persons on the roads.

What is the probability of a debris flow?
How big will the debris slide be?
How far will the debris slide flow and what will be their flow path?
What is the probability of a property or person being hit by a debris slide?
What is the vulnerability of property and persons?
What are the risks to property and persons?
What are the acceptable criteria for evaluating risk?
4.1 Introduction

Risk Treatment is the ultimate aim of Risk Management and provides the tactic of mitigating the effect of the natural hazard. Once the risk has been analysed, the strategy is to identify the options and methods for minimizing it. Some typical options would be to accept the risk, avoid the risk, reduce the likelihood, reduce the consequences, install monitoring and warning systems, transfer the risk, or, if there is sufficient uncertainty from the available data, postpone the decision. The relative costs and benefits of the options are required to be considered so that the most economic solutions, consistent with the overall needs can be identified. Combination of options or alternatives may be appropriate, particularly where relatively large reduction in risk can be achieved at relatively small cost. A treatment plan for each option may be used to delineate how the option will be implemented. Each plan also needs to identify responsibilities for each stakeholder during and after implementation, the extent of work required, cost estimates and programme, performance of measures and the expected outcome. Monitoring of the treatment plan and risks is needed to ensure that the plan is effective and changes in circumstances do not alter risks. It is essential to reconsider all stages of the analysis, assessment and prioritisation as the treatment plan evolves and is implemented. The results of monitoring may enable feedback for reassessment of the risks.

Landslide risk can be mitigated by five approaches used individually or in combination, to reduce or eliminate losses.

Restricting Development in Landslide-Prone Areas: Landuse planning is one of the most effective and economical ways to reduce landslide losses by avoiding the hazard and minimizing the risk. This is accomplished by removing or converting existing development or discouraging or regulating new development in unstable areas. However, in many States in our country, there are no widely accepted procedures or regulations for landslides.

Codes for Excavation, Construction and Grading: Excavation, construction and grading codes have been developed in many countries for construction in landslide-prone areas. There is no uniform code to ensure standardization in the country.

Protecting Existing Developments: Control of surface and subsurface drainage is the most widely used, and generally the most successful, slope-stabilization...
methods. Stability of a slope can be increased by removing all or part of a landslide mass, or by adding earth buttresses placed at the toes of potential slope failures. Retaining / Restraining walls, piles, caissons, or rock anchors, soil nailing are commonly used to prevent or control slope movement. In most cases, combinations of these measures are used.

**Monitoring and Warning Systems:** Monitoring and warning systems help to protect lives and property, these cannot to prevent landslides. However, these often result in issuing warning of slope movement in time to allow the construction of physical measures that will reduce the immediate or long-term hazard. Site-specific monitoring techniques include field observation and the use of various ground motion measuring instruments, trip wires, radar, laser beams, and vibration meters. Data from these devices can be telemetered for real-time warning.

**Landslide Insurance and Compensation for Losses:** Landslide insurance would be a logical means to provide compensation and incentive to avoid or mitigate the hazard. Landslide insurance coverage could be made a requirement for mortgage loans. Controls on building byelaws, development, and property maintenance would be needed for mandatory insurance. Insurance and appropriate government intervention can work together, each complementing the other in reducing losses and compensating victims.

### 4.2 Mitigation Measures

#### 4.2.1 Structural measures:

Adopt remedial techniques (i.e., buttresses, shear keys, sub-drains, soil reinforcement, retaining walls, etc.) of existing landslides that are in close proximity to public structures.

#### 4.2.1.1 Drainage Corrections:

The most important triggering mechanism for mass movements is the water infiltrating into the overburden during heavy rains and consequent increase in pore pressure in the overburden. Hence the natural way of preventing this situation is by reducing infiltration and allowing excess water to move down without hindrance. As such, the first and foremost mitigation measure is drainage correction. This involves maintenance of natural drainage channels, both micro and macro, in vulnerable slopes.

#### 4.2.2 Non-structural Measures

##### 4.2.2.1 Proper landuse measures:
Adopt effective landuse regulations and building codes based on scientific research. Through landuse planning,
discourage new construction or development in identified hazard areas without first implementing appropriate remedial measures.

4.2.2.2 Afforestation: The afforestation programme should be properly planned so the little slope modification is done in the process. Bounding of any sort using boulders etc. has to be avoided. The selection of suitable plant species should be such that can withstand the existing stress conditions of the terrain.

4.2.2.3 Awareness generation: Educate the public about signs that a landslide is imminent so that personal safety measures may be taken.

Some of the 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) Sticking doors and windows, and visible open spaces
(v) Broken water lines and other underground utilities
(vi) Leaning telephone poles, trees, retaining walls or fences
(vii) Sunken or dropped-down road beds
(viii) Rapid increase in a stream or creek water levels, possibly accompanied by increased turbidity (soil content)
(ix) Sudden decrease in creek water levels even though rain is still falling or just recently stopped

4.3 Three elements for translating technical information to users

i. Likelihood of the occurrence of an event of a size and location that would cause casualties, damage or disruption
ii. Location and extent of the effects of the event on the ground, structures or socio-economic activity
iii. Estimated severity of the effects on the ground, structures or socio-economic activity

Translate hazard information so that nontechnical users are also able to perceive likelihood, location and severity of the hazard.

Mitigation includes any activity that prevents an emergency, reduce the chance of an emergency happening, or lessens the damaging effects of unavoidable emergencies. Investing in preventive mitigation steps now such as planting
ground cover (low growing plants) on slopes, or installing flexible pipe fitting to avoid gas or water leaks, will help reduce the impact of landslides and mudflows in future. For more information on mitigation, contact your local emergency management office.

4.4 Techniques For Reducing Landslide Hazards

Discouraging new developments in hazardous areas by:
- Disclosing the hazard to real estate buyers
- Posting warnings of potential hazards
- Adopting utility and public facility service-area policies
- Informing and educating the public
- Making a public record of hazards

Removing or converting existing development through:
- Acquiring or exchanging hazardous properties
- Discouraging non-conforming uses
- Reconstructing damaged areas after landslides
- Removing unsafe structures
- Clearing and redeveloping blighted areas before landslides

Providing financial incentives or disincentives
- Conditioning financial assistance by the state or by central government
- Clarifying the legal liability of property owners
- Adopting leading policies that reflect risk of loss
- Requiring insurance related to the level of hazard

Relating to new developments in hazardous areas by:
- Enacting grading ordinances
- Adopting hillside development regulations
- Amending landuse zoning districts and regulations
- Enacting sanitary ordinances

Protecting existing developments by:
- Controlling landslides and slumps
- Controlling mudflows and debris flows
- Controlling rockfalls
- Operating monitoring, warning and evacuating systems
- Emergency plans (life-saving, evacuation and facility specific)
Investigation of Landslides
The investigation of landslides should be carried out in the following sequence

5.1 Preliminary Investigations

5.1.1 Collection and Review of Existing Data,
Landslides often occur at specific locations under certain topographic and geologic conditions. Therefore, it is important to utilize existing data (history of the problem, records of restoration work, and data review) along with the topography, geology, and properties of similar landslides. It is also important to understand their relationship with meteorologic factors such as rainfall, period of activity, existence of any warning sign, ground water conditions, chronology of topographic change or erosion by rivers, earthquakes, and other factors which may have a relationship with the slope deformation/displacement surrounding the investigation site area prior to the detailed investigation.

5.1.2 Topographic Investigations
It is necessary to identify any changes in the site topography. That can be accomplished by recognizing;

- a) the overall topographic feature of the site;
- b) understanding the topographic characteristics of the site slopes; and
- c) estimating the regional geologic structure of the site.

Such methods include comparing the aerial photographs of the site and vicinity taken prior to and after the sliding, and interpreting the topographic maps and aerial photographs. The latter can be used to understand the chronologic and topographic changes over a period of time. By utilizing aerial photographs, it is possible to interpret landslide phenomena and warning signs, geology and geologic structure, topography and distribution of vegetation types. For landslide investigations, it is useful to identify and interpret the distribution and continuity of knick points, gentle slopes, gullies and cracks in the photos to aid in preparing a photo interpretation map which can then be utilized during field investigation.

Remote sensing using satellite imageries has been particularly useful for estimating the distribution of slide areas and ground water, and vegetation at
regional levels. Remote sensing can also be used for analysis of topographic characteristics in terrain susceptible to landslides

5.1.3 Field Investigations

With an assessment of the overall topographic features and knowledge of the distinctions of movement and areal extent of the sliding blocks (viewed from the opposite hillside), a detailed field investigation plan can be developed to delineate the areal extent and a general direction of movement of the landslide zone, assess the lithologies and geologic structures, estimate the causes of the sliding, and predict future movement. The field investigation should not include just the actual landslide area, but also extend to slope limits or local drainage basin area. The field investigation should also include areas where aerial photographic interpretation is difficult or unclear, and in areas that could aid in the understanding of particular topographic features and characteristics.

5.2 Preparing a Detailed Investigation Plan

A detailed investigation which will satisfy the following objectives, should be planned.

(i) areal extent of the slide, differentiation of moving blocks and identification of the type, direction and extent of movement; if possible, the time and duration of movement as well
(ii) location and shape of slide planes
(iii) nature of landslide blocks
(vi) possibility of further or future movement on slopes above the existing slide
(v) possibility of further, future or accelerated sliding
(vi) distribution of ground water and heterogeneity of slope mass

5.2.1 Survey lines can be established on each moving block on the ground where the slide mass is expected to be thickest and where the stability analysis and plan for control works will be emphasized.

5.2.2 Exploratory borings: At least three borings should be drilled along the main survey line with one going at least 5 to 10 m below the slide plane. During the early stage of investigation, it is particularly important to have an accurate estimate of the configuration and location of slide plane(s) for planning an adequate boring depth (Figs. 5.11 & 5.12).
5.2.3 Geophysical survey: Seismic survey should be conducted along the main survey line as well as along the longitudinal survey lines that cross the main survey line and subsidiary survey lines. For the seismic survey, the survey points should be established at 5-10m intervals, and for electrical surveys, 20-50m. Furthermore, to verify the results of the geophysical surveys, it is important to drill at the survey line intersections.

5.3 Geological Investigations

Landslide investigation and mitigation, requires mapping landslide hazards and creating a knowledge/database with the fullest appreciation of the scale and degree of reliability of the information gathered. For estimation of destructive potential of a landslide, one needs to know its expanse/spatial extent and also time scale of landslide activity, mechanism, run out distance, elements at risk and recurrence history. For prediction of a landslide, one needs to find out where and when will it occur and how far and how fast will it move. For design of control measures to manage landslides, one needs to know what the landslide type is (its classification), what could be different possible modes of failure, where are the slide boundaries, what the operating shear strength characteristics of boundary shears and how will the pore pressures vary on slide boundaries with time. For measuring the efficacy of control measures, one would need to know the actual performance of the slope measured vis-a-vis the design performance. The plan of geotechnical investigation should clearly state its purpose.

The term geological investigation covers both surface and subsurface explorations to be carried out for determination of the extent of the landslide in all the dimensions, nature and disposition of geological formations, structures in the area, physical and geotechnical characteristics of the material involved in the landslide process and factors responsible for activating the slide and severity of hazard. The extent of geological investigations should be planned keeping the above factors in view.

5.3.1 Preliminary Stage Geological Investigations

The preliminary stage investigations involve collection of available information, desk studies as well as initial recognoitory traverses in field to collect regional as well as local information and data. Extensive use of remote sensing products including high resolution CARTOSAT-1 & 2 should be made to demarcate the area likely to be affected further to understand the dynamic behaviour of slide, delineate modified slope conditions by preparing DEM etc.
Field Surveys and Investigations: The first task to be taken in the field after finishing the desk work is to verify and validate the data collected during desk studies and plan further course of work. The preliminary field surveys in the slide area should be carried out with a view to assess:

i) The dimensions, geometry and nature of the landslide and status of sliding activity.

ii) The condition of the ground beyond the boundaries of landslide.

iii) Record orientation, spacing and openings of all cracks.

iv) Disposition of zones of accumulation, depletion and scarp faces and distribution pattern of different size fractions in debris.

v) Disposition, attitude of bedding, foliation and all other planar structures, lithological variation of rocks, state of weathering, joint/fracture spacing, openness, roughness, continuity, joint/fracture wall alteration etc.

vi) Locations of seepage, spring, natural drainage courses and slushy ground.

vii) Recording the movement of different parts of slide during period of investigation.

viii) Location of human habitation, communication corridors and other civil engineering structures.

ix) Weathering profile, nature of slope forming material, study of overburden and rock contact, nature of drainage, springs, scarps etc.

x) Demarcation of Buffer zone based on the trajectory of the falling rock blocks, between the toe of the hill and the human settlements or other structures to avoid any risk factor during treatment of the slide.

5.3.2 Detailed Geological Investigations

The detailed geological investigations, both surface and subsurface, which are required to be carried out at this stage are further to the studies already carried out. The extent of area to be covered by geological mapping and the extent of subsurface geological investigations required are guided by the geological complexity of the site. Detailed investigations at this stage should be planned and executed in close cooperation and interaction between engineering geologist and geotechnical engineers.

After completion of surface geological mapping, the behaviour of surface material and other features in depth are required to be explored. The subsurface explorations required for this should aim to establish:
• Depth to bedrock or thickness of overburden and weathering limit. Lithological characters of various rock units and their significance, limit of slump joints and glide cracks, if any.
• Nature, condition, opening, spacing and continuity of prominent joints, slip surface, minor and major shear zones, etc.
• Depth of ground water table.
• Permeability of strata and
• If possible, the depth and disposition of plane along which failure has taken place.

The above parameters can be determined by employing non-destructive geophysical techniques that are easily available. Geophysical exploration should be done especially in the areas covered by debris or river-borne material/terrace deposits. Geophysical surveys including, resistivity surveys, seismic refraction surveys have been found helpful in determination of above parameters. With developments in electronic and software technologies, the results are becoming more and more precise, accurate and dependable.

Ground Penetrating Radar (GPR) can be initially employed in such surveys for evaluating depth and nature of bedrock and also ground water conditions. GPR surveys are very quick and provide results quickly. These can be followed by seismic (reflection) and resistivity surveys.

The preliminary and detailed geological investigations of landslides constitute the bedrock on which sound geotechnical investigations must be built. Detailed guidelines will be developed on diverse aspects of slope engineering for ensuring systematic geological investigations and mapping.

5.4 Geotechnical Investigations

These include mapping of problematic slopes on an appropriate scale, scientific understanding of its kinetics, elucidation of landslide boundaries, determination of representative shear strength parameters, pore pressure variations on the slide boundaries and finally evaluation of factor of safety. It is important to understand the distinction between the first time and the reactivated slides. The boundaries of the former are not known in advance and also the investigation needs and mitigation measures for imminent landslide of this kind may be different.

Geotechnical Investigation for mass movements like rapid motion landslides, multi-tier landslides, rock falls, debris flows and avalanches may throw
up many other investigational requirements. There could also be cases of landslides changing their character. For instance, in its wetter manifestation, a landslide may partake the character of a flow and acquire rapid motion. In such cases, laws of fluid dynamics may take over from the laws of classical soil mechanics.

A good geotechnical slope investigation is usually driven by the leads thrown up by the large scale geomorphological map of the area. It should always begin with careful study of field evidences that can be closely observed by a trained landslide investigator. For instance, study of the slide boundaries, surface geology, discontinuities, shear zones; water springs, aquifers, slope subsidence, heave, cracks and behaviour of buildings/walls/floors etc., provide a sense of direction to the nature and quantum of ensuing detailed sub slope geotechnical investigations. A vigilant eye can express much more by looking at an exposed roadside cutting than the whole gamut of geotechnical investigation made after huge expense of time and money. No amount of drilling can ever replace the practice of observing and careful characterising the fissures, slip surfaces and shear zones, joint fillings, the erratic nature of soil profiles, the sand and the silt lenses, the solution cavities, the evidences of underground erosion and more, visually seen in the open exposures and cuttings.

No matter how thorough is the geotechnical investigation, uncertainties involved would always call for making design assumptions based on engineering judgment. Every geotechnical report must clearly state the assumptions made and the basis there of. It would, therefore, be a big mistake to prescribe a rigid programme of soil investigation at the outset. The best soil investigation programmes are those which advance and get modulated with every new shred of investigational information.

A geotechnical investigation often tends to get expensive and even wasteful if it does not relate closely to the slope information to be gathered and answer the specific questions. For instance, it has become a common practice to prescribe an extensive programme of drilling to locate basal boundary shear of a landslide even without a site visit. One must remember that even with extensive drilling, the basal boundary of a landslide may defy attention in the core logs. Imagine the savings and time effectiveness in investigation that will accrue if one were to succeed in locating traces of basal boundary shears in, for example, a road side cutting.
Selection of equipment for slope investigation, drilling and in situ testing and decision on scale, scope and type of undisturbed sampling and laboratory testing are highly specialized matters. The present tendency of making divergent uninformed choices without adequate scientific reasoning must end. There is a need to develop guidelines on this, especially for the training of geotechnical engineers engaged on landslide projects as also for the benefit of those responsible for building institutional capacities.

Deterministic analyses of slopes can be either two or three dimensional. The former under-estimate the factor of safety and are, therefore, done where either side resistance to landsliding is negligible or uncertainties are large and quick conservative designs are required for further planning. For important projects where high quality investigation is mandatory, a three dimensional analyses should be done for ensuring economy in design. Since there are uncertainties involved at various steps of investigation and design, and it is not always possible to justify single value inputs, the need and merit of probabilistic analyses of slope must also be considered.

Deterministic analyses could either be in terms of effective stress or as total stress. The unhealthy practice of ignoring this essential requirement must stop. There is a need to develop guidelines for scientific analyses of slopes and landslides in terms of total and effective stresses as the ground situation demands. Every report will specifically point out assumptions made and limitation of the data used in slope analyses and design. The efforts must clearly focus on neglected but vital aspects such as techniques of undisturbed sampling of shear zones and boundary shears and evaluation of shear strength parameters using appropriate stress path. It is often meaningless to spend money doing tests such as SPT and DCPT in drill holes or unconfined compression tests in a laboratory, since shear strength is not a unique property of a soil sample. Laboratory tests without obtaining representative high quality undisturbed samples and without picking the right type of test could also be misleading. Besides, one must remember that soils are non-homogeneous and anisotropic and their non-linear behaviour is greatly influenced by their stress-strain history and structure.

Most landslides being the result of poor slope and sub-slope drainage, detailed hydrological studies of the catchments associated with landslides are essential. In the areas of complex landforms with water streams, springs and ill defined overland flow; radioisotope studies are often useful to map subterranean water flow while investigating the causative factors of a landslide.
Landslides Investigations

For achieving the objectives of an investigation, the coupling between study of landslides through remote sensing and ground surveys should be logical and strong. Landslide investigation without remote sensing is often blind. By the same logic, landslide investigation without ground studies and validation is lame.

Landslides in meta-stable deposits of granular (sandy) nature, especially in the high rainfall areas, tends to liquefy due to seismic shock or external vibration. Similarly earthquake-induced landslides could be co-seismic or post-seismic.

Reference to geotechnical reports prepared for different civil and infrastructure development projects at or close to the location of a landslide will serve the triple purpose of consolidating the available body of geotechnical information, pinpointing the inconsistencies, inadequacies and gap areas and provide a cost-effective and sound basis for deciding the geotechnical scope of a landslide investigation.
Fig. 5.1: Triaxial Test apparatus for evaluating strength parameters

Fig. 5.2: Stress Path Triaxial Test System

Fig. 5.3: Computer Controlled Consolidometer

Fig. 5.4: Laser Particle Size Analyser

Fig. 5.5: Computer Controlled Triaxial Test Equipment

Fig. 5.6: Indigenous instruments (Tiltmeter, Crackmeter, Pressure Cells) for slope monitoring
Fig. 5.7: Triaxial Testing equipment for strength parameters of rocks

Fig. 5.8: Compressive strength test equipment for rocks

Fig. 5.9: Indigenous Open stand-pipe type piezometer

Fig. 5.10: Electrical Strain Gauge Equipment

Fig. 5.11: Use of bore hole camera to study bore wall

Fig. 5.12: Core logs used to identify and grade subsurface materials
6.1 Slope Instrumentation, Monitoring and Landslide Prediction

Slope instrumentation for monitoring and prediction of landslide has so far not been a general practice in our country. A few attempts have been made by some institutions but the methodology and techniques as well as the results are not uniform. Thus, the efficacy of slope monitoring through instrumentation has remained a non-starter. The detailed slope stability analysis and modeling of a landslide are almost impossible without instrumentation. Monitoring indicates acceleration of movement and development of pore pressures at different locations within the slide mass. Interpretation of data is difficult as critical values are unknown unless there is documented history of previous events. It is not practicable to monitor all the landslides by the installation of instruments considering the prohibitive cost and infinite landslide incidences in the country. The monitoring system of landslide can also be used for alerting the people about impending disaster.

6.2 Early Warning of Landslides

The Early Warning Systems elsewhere in the world have been developed by Real Time Automated Monitoring of landslide parameters. These include monitoring the movements, development of stresses, and pore pressures or hydrostatic pressures continuously and transmission of instrumental generated data through telemetric system at regular time intervals. At the initiation of an event, the radio signals are transmitted and alarm signals sent to the relevant authority regarding the probable time of occurrence and impending danger of the landslide. However, generating awareness and involvement of local communities is vital component of an early warning system. Therefore, for an early warning system to be successful it is necessary that local people are associated with it. In certain cases they, if properly trained and adequately motivated can observe the movement indicators on hill slopes and issue necessary warnings.

The Real Time Automated Monitoring for the development of an Early Warning System may be undertaken for a few devastating, large dimension and recurring types of slides or rock falls which are very difficult to stabilize.
and pose high risk. Since the ultimate goal is to find out a permanent solution to stabilize the slide, the development of Early Warning System is not the ultimate answer to this natural hazard, but it is a part of the effort to mitigate its impact.

Considering the probable danger of loosing the instruments due to recurrent nature of some of the conspicuous landslides and prohibitively high cost of them, an effort may be made to develop the early warning system for those devastating landslides where instrumentation would be proposed as it will serve the twin purpose i.e. detailed slope stability analysis for suggesting the most appropriate remedial measures or development of an early warning system by real time monitoring of landslides. The experience gained from this type of exercise will be immensely helpful for studying other landslides.

6.2.1 Monitoring of Landslides

Monitoring of landslides movements consists of:

- Selection of specific location depending upon the type of movement, location and hazard and risk value of slope failure.
- Selection of monitoring methods and frequency of data collection.
- Data processing and methods of presentation / communication of results.

Methods generally used for monitoring landslide can be divided into surface and subsurface measurements of the landslide activity and total regime measurements.

6.2.1.1 Surface Measurements of Landslide Activity

Simple method of monitoring is installation of a few survey pillars within a landslide zone and on its periphery and linked with a few reference pillars installed on undisturbed and stable ground. Periodic observations of the relative position and top level of survey pillars particularly in pre, during and post-monsoon periods give a fairly good idea about the extent and rate of surface movement of the slide, amount of subsidence and also surface stress variations. The rainfall data, particularly the intensity of rainfall should be collected from the nearby rain gauge station and an effort may be made to correlate the intensity of rainfall data with time of initiation of the mobilization event. Measurement of cracks on surface of the slope and their development provides very useful input to slope stability analyses.
6.2.1.2 Subsurface Measurements of Landslide Activity

Subsurface measurements of landslide activity are carried out by installing different types of instruments in boreholes drilled at various identified locations. The shallow subsurface movements including creep are measured by installing flexible casings in boreholes and observing their behaviour; SGI rod Inclinometers; Kirby’s T- pegs and Strain Probes. The movements at deeper depths are monitored through Chain Deflect meters, Single or Multi Drill hole Extensometers; Single and Multi Point Wire Extensometers; Pipe Strain Meters and Insert Type Pipe Strain Meters. However Slope Indicators and Inclinometers are most extensively used for monitoring the subsurface movements in landslides. Geophysical method of measuring pulse electromagnetic emissions identifies the zones of high stress concentration in the body of the slide. The measurements can be taken in the inclinometer boreholes.

6.2.1.3 Total Regime Measurements

The total regime measurements include recording fluctuations in the behaviour of ground water, which is most often the principal cause of sliding. The purpose of these observations is to record changes in ground water levels, yield of water and consequent development of pore pressure in the slide material. The behaviour of ground water in the slide area can be measured and monitored by installing piezometers at different depths in the boreholes. Of the various types of the piezometers, the Hydraulic, Pneumatic and Electrical Piezometers are most commonly used. Of late, Tensiometers are used for measurement of negative pore water pressure.

Recording rainfall is required to develop correlations between rainfall, slope movement and pore pressures in the slide mass and also impact of these on initiation of slide activity. The rainfall should be measured by installing automatic rain gauges at the slide location.

6.2.2 Real time Automated Monitoring of Landslide

Simple monitoring of landslides, with or without instrumentation, cannot detect changes at the time of initiation of the mobilization event while the real time automated monitoring of landslides can continuously pick up even minor changes enabling transmission of warning signal just at the time of initiation of a slide movement. The continuous data provided by real time automated monitoring through a remote station permits better understanding of dynamic behaviour of a landslide. With rapid advances made in electronics and communication technology, it has become possible to monitor the
behaviour of a landslide continuously and transmit data to processing locations on real time basis. All the instruments are connected to data loggers located in the vicinity of the sites being monitored. The data loggers are connected to data processing stations through telemetry systems that can transmit data to processing stations on real-time basis. The data thus obtained can be processed automatically and immediately by computers having necessary softwares. The results can be utilised for maintaining the records or for issuing warning as per requirements.

Recently, the remote sensing application tools, including High Resolution Satellite Imagery, Light Detection and Ranging (LIDAR), Synthetic Aperture Radar (SAR), Persistent Scatterer (PS), Synthetic Aperture Radar, Differential Interferometry techniques for the correlations between landslide morphology, motion and topographic analysis are used in some countries for landslide monitoring. It has facilitated predictive modeling and risk analysis of a landslide.

These and related studies demonstrate the rich potential of using new technologies for landslide studies. Clearly, the recent advances especially during the past two decades in remote sensing, digital image processing, GPS, and GIS have revolutionizing the study of landslides and improving the ability of the scientific and government agencies to monitor and manage landslide-prone areas. In particular, GPS can play an important role in monitoring landslide-prone areas for signs of current movement, and provide near real-time warning of motion on slides that can endanger life and property. With the advent of multi-antenna GPS instruments, the cost of monitoring by GPS has come down substantially. High resolution imagery and topographic mapping can lead to improved understanding of landslide mechanics and hazard prediction. Continued research into methods of data collection, processing, and synthesis is needed to realize the full potential of these technologies for worldwide use in the coming decades.

Real Time Automated Monitoring of landslide is not generally practised in India till date. As real time monitoring of landslide is a costly procedure involving high risk of losing the expensive instruments due to active nature of the slide, landslides having the potential to collapse catastrophically and threatening lives and property, should be identified and monitored on real-time basis.

6.3 Investigation of Surface Deformation

The investigation of surface deformation is conducted to define the boundaries of landslide, its size, level of activity and direction of movement,
and to determine individual moving blocks of the main slide. Presence of scarps and transverse cracks are useful for determining whether there could be future activity.

**6.3.1 Instrumentation** used for the surface deformation investigation includes extensometers, ground tiltmeters, movement determination by survey methods including transverse survey, grid survey, laser survey from the opposite bank, movement determination by aerial photographs, and G.P.S.provides an example of instrumentation.

**a). Extensometer**
The extensometer (Fig.6.4) is used to measure relative movement by comparing the extension of two points over a period of time. The extensometers are generally installed across the main scarp, at transverse crack and at transverse ridges near the toe or front portion of the slide and parallel to its suspected movement. By arranging a series of interconnecting extensometers from the main scarp to the toe of a complex landslide that has multiple slide blocks, the resulting data could aid in clearly delineating the individual block. Measurements should be accurate to within 0.2mm, and the magnitude of the movement and daily rainfall data should be included to establish the relationship between the measurable movement and the precipitation / infiltration.

**b) Tiltmeter**
The ground tiltmeter (Fig.5.6) is useful in determining the deformation at the head and the toe portions and sometimes along the flanks of landslide, or to assess the possibility of future deformation. A level type tiltmeter is most conventional. The tiltmeter is capable of measuring the N-S and E-W components. The magnitude and directions of tilting can be determined directly. Furthermore, in order to determine the characteristics of the deformation, the results are shown chronologically along with daily rainfall totals. The relationship between the magnitude of tilting and the cumulative effect of tilting, rainfall totals and groundwater levels should also be plotted.

c) **Differential Settlement Gauge** (Fig.6.3)

d) **Crackmeter** (Fig.6.6)

(i) **Simple Method to Measure Movements**

One simplest method to determine landslide movement is to drive wooden stakes across a tension crack along the direction of slide movement. Then attach horizontal boards to the stakes, and saw through the boards. Any movement
across the tension crack can be determined by measuring the space between the sawed portions of the boards.

(ii) **Determination of Movement by Surveying** (Transverse Survey, Grid Survey, Laser Survey From the Opposite Bank of the hill, Movement Determination by Aerial Photographs, and G.P.S.).

**Transverse Survey:**
This survey method establishes transverse survey lines across the landslide blocks with closely-spaced survey stakes. The survey stations should be established both within the slide and outside it on stable ground.

**Grid Survey:**
This survey method involves constructing grid lines across the entire landslide as well as on stable ground, outside it. The survey stakes are driven at the intersection of the grid lines.

**Laser Survey from the Opposite Bank:**
A control point (Fig.6.14) is established along the opposite bank on stable ground, and survey stakes are positioned within the slide (Figs.6.8, 6.9, 6.10 & 6.13). It is most effective where movement in large.

**Movement determination by Aerial Photographs:**
For landslides with a large component of movement, aerial photographic determination extremely useful. An accurate movement can be measured by annual or bi-annual flying.

**G.P.S.:**
Global Positioning System is the state of the art technology that uses signals from satellites to determine the three-dimensional positioning of the slide. G.P.S. has been used in recent landslide investigations where high degree of success results (Figs.6.5, 6.11 & 6.12).

**Automating Survey System**
In the past, measurements of slope deformation were being performed manually. Recently, automatic survey systems using data loggers and computers have been adopted (Figs.6.15 to 6.18). The instrument set-up in the field has been so designed that it is easy to install, and is weatherproof, durable, maintenance-friendly and economical. Through remote control in real time and rapid geographical data processing, it is possible to store long term data accurately and effectively and provide an early warning of impending slide, thereby reducing landslide risk. Furthermore, taking benefit of the recent development
in the information based construction systems and adopting the safety control system using the real time at the construction site would facilitate the planning through construction stage.

There are three main advantages in using the automated survey system

i) Surveillance of the conditions of landslide failure: Issuance and cancellation of landslide watch and warning announcement based on the velocity of movement, piezometric pressure and variation in the quantity of rainfall. Prediction and forecasting of the landslide failure.

ii) Understanding of the conditions of the landslide deformation: Chronological measurements of movement velocity. Determination of the slide plane depth. Determination of the relationship between the slope deformation and factors of slide occurrence (pore water pressure against the slide plane, critical pore water pressure related to the time of sliding, rainfall and snowmelt).


6.4 Investigation of Geologic Structure

Mostly this is accomplished by exploratory borings; however in cases where the bedrock distribution is ambiguous or a better understanding of the regional geologic structure is needed, geophysical exploration (seismic and electrical surveys) is added to the boring data.

A) Borings

Majority of the borings are of NX (76mm) size. Core samples are recovered from the borings and are stored in core boxes. Core logs should be prepared along with photographs of the core sample and should include information on geologic and soil description; color; hardness; lithologic description; degree of weathering; alterations and fractures; strike and dip of bedding joints; boring conditions; initial and stabilized ground water levels; and rate of core recovery.

Geologic assessment based on the boring data obtained from the drilling site should include a discussion regarding the differentiation of moving earth blocks, semi-moving earth, and stable ground. Clays within the slide plane
generally have a high moisture content, are highly sticky and plastic and are often associated with abrasion scars and slickensides. During drilling, squeezed earth could occur near slide plane. Slopes where advanced relaxation of the bedrock formation has occurred will often exhibit gentler slopes than that of the unaffected bedrock zone. Formations can bend or form a kink bend near the lower limit of this zone, and could develop into a slide plane. In translational dip slope slides, the slide plane in many instances will develop along a thin, weak bed of mudstone, tuff bed or coal seam sandwiched between hard and competent beds. Borings can sometimes easily miss these thin beds. Therefore, the possible existences of slide planes along these weak beds typically consist of about 10cm wide/thick, and must be considered even though the boring may not indicate their presence.

Furthermore, using the data from the borings, the following information must be assessed or determined.

- Evaluation of slide plane
- Ground water level measurements
- Ground water logging
- Ground water tracer tests
- Standard penetration tests, Horizontal loading tests, In-situ tests such as in situ permeability tests
- Sampling for soil tests
- Geophysical logging

B) Geophysical Surveys

Geophysical surveys (seismic and electric surveys) aid in visualizing the subsurface conditions like dimension and nature of slide material, the lithology, structure and other geological characteristics of the enclosing rocks and the presence and extent of water bodies. In the seismic method, P-wave refraction technique is more commonly used than S-wave and P-wave shallow refraction techniques. P-wave refraction surveys are the most common seismic survey. Other methods, such as S-wave and P-wave shallow refraction, are seldom used. Electric survey is the specific resistance method and is applied to determine the distribution of aquifers and to understand the geologic structure. These surveys include the development of the geotomography method. In some countries, a natural radioactivity survey is used to determine the locations of small fracture zones and cracks.
6.5 Evaluation of Slide Plane / Monitoring of Sub-surface Movements

Determination of the slide plane for actively moving landslides utilize the fact that the rates of movement differ significantly along the slide plane. Depending on the need for surveying accuracy and magnitude of movement, the appropriate instrumentation is selected from the following representative instruments;

a) Pipe strain gauge
b) Inclinometer
c) Multi-layer movement meter
d) Other methods

a) Pipe Strain Gauge

P.V.C. pipes with strain gauges are inserted into the pre-drilled boreholes; the movement causes P.V.C. pipes to bend and their shift is estimated by the change in the strain. The accuracy of the strain gauge can be increased by reducing the intervals of the gauge, however, it is acceptable to widen the space upto 1m for investigations involving very thick slide materials and where it is difficult to handle the survey extension wires. The two lowest strain gauges must be anchored into the bedrock below the slide plane so that data of the stable formation is also obtained. Furthermore, annular space between the borehole and the pipe must be filled with concrete following the gauge installation. The instruments should last at least for one or two years

b) Inclinometer (Figs.6.1 & 6.2)

A grooved casing is inserted into the borehole extending into the bedrock formation, and adequate quality of grout placed into the borehole to assure positive contact with the borehole. By lowering a probe equipped with a tilt sensor, deformation in the casing can be detected and movement of a landslide determined. An accurate measurement is possible where the deformation of landslide is relatively small. As the landslide movement increases, the borehole and casing will bend making insertion of the probe difficult or will exceed the tilt detection limit of the instrument.

c) Multi-Layer Movement Meter

Several wires are anchored at different depths in a borehole and the attached wires must extend up to the ground surface. The magnitude of the displacement of each wire segment can be measured directly using a ruler. It is possible to install 20 to 30 wires per borehole. This method is not suitable for landslides
with small displacement and is most effective where the slide movement is so large that other instruments do not work. Applying the same principle, a vertical extensometer can be formulated by fixing a wire on the bedrock at the bottom of the borehole.

e) Other Methods

Other methods to evaluate the slide plane include: slide plane detection probe; creep wells; and sounding penetration test.

6.6 Groundwater Investigation

Investigation of ground water, which is a driving force of sliding, includes determining ground water level, pore water pressure, ground water logging, ground water tracing test, pumping test, water quality analysis, electrical and geothermal surveys, and geophysical (electrical and radioactive) loggings. Based on the results of the above measurements and tests, ground water control works can be planned, designed and put to use.

a) Ground Water Level Observation

As a general rule, ground water levels should be measured in all the boreholes. In some of the more important boreholes, continuous rainfall data should be obtained by installing automatic recorders to determine the correlation between the slide movement and rainfall and ground water level, and also collect data on the ground water distribution and its movement regime.

b) Pore Water Pressure

Ground water levels in boreholes will often reflect seepage from highly fractured formations or indicate the water level of a predominant aquifer. Therefore, for stability analysis, it is best to measure pore water pressure along the slide plane. Sometimes it is difficult to accurately estimate the depth of the slide plane. In such cases it is desirable to install piezometers (Fig.5.9) in the beds with low seepage or low shear strength. The standard piezometers for landslide investigations must be open piezometer water level type and should be durable.

c) Ground Water Logging

Flow of ground water and flow directions can be determined by computing the increase in specific resistance of ground water in flow over a period of time. The measurements should be continued after lowering specific resistance of ground water by injecting a salt solution into the borehole. There should be at least two borings for ground water logging at the head portion of the landslide where abundant ground water is expected. The measurement results should be recorded along with the boring logs, and the relationship between the
location of ground water flow and bed, and magnitude and variation of specific resistance of ground water should be discussed. Furthermore, the results of the analysis should be recorded along with the cross sections in order to understand the overall ground water flow.

d) Ground water Tracer Tests

Tracers such as a soluble dye, or inorganic chemicals (NaCl) are injected into a borehole. Water samples are then collected chronologically from springs, other boreholes, wells and ponds within or outside the landslide, and are analyzed for the tracer to estimate the ground water flow direction(s) and permeability. This data is used as basic information for developing the design of dewatering works.

e) Drawdown Test

In order to estimate the yield and to calculate the coefficient of permeability, water within a borehole is pumped to certain levels after raising the boring casing every 2 to 3m. A time-recovery curve can then be plotted using Jacob’s and other formulae, and the coefficient of permeability can thus, be determined.

f) Water Quality Tests

Water quality testing is an effective way to examine the distribution of the ground water regime and flow directions where landslides are very large and the ground water system is expected to be complicated. Specific tests include determination of water temperature, Cl⁻, SO₄²⁻, HCO₃⁻, Na⁺, K⁺, Ca²⁺, and Mg²⁺ content, pH, alkalinity, electric conductivity, SiO₂, and others. The test results are classified according to the analytical data and composition.

g) Geothermal Investigation

This procedure utilizes ground temperature measurements in the entire study area, including ground temperatures near the ground water veins. By measuring the temperature differences at non-ground water areas and near ground water veins, it is possible to isolate the ground water veins where the temperature difference between the two is large. By conducting the geothermal investigation in summer and winter months when near surface ground temperature is influenced by air temperature, good results have been obtained for the isolation of relatively shallow ground water.

6.7 Geotechnical Investigations (Soil and Rock Mechanic Tests)

In order to conduct slope stability analyses and to design appropriate control measures for landslides, physical properties such as strengths, location and
depth of slide plane and stable ground areas must be determined. The following tests are generally performed; physical tests, Standard Penetration Tests, soil and rock mechanic tests (unconfined compression, tri-axial compression, box shear, ring shear, and in-situ shear (along the slide plane)). In order to obtain the earth reaction coefficient for the design of the restraint works, there is currently a tendency to conduct more horizontal loading tests and plate loading tests to determine the modules of deformation. Furthermore, the intensity and degree of alteration of the slide plane clays are evaluated by X-ray diffraction methods. The results have also been applied to analyze the origin of the slide plane.

6.8 Early Warning Systems for Landslides

In a holistic sense, the term early warning includes the whole range of actions and operations right from stages of planning and instrumentation of problematic slopes and landslides to their monitoring, analyses, fixing of early warning alert thresholds, decision making, dissemination of early warning alerts and recurring improvements in early warning practice through sustained location-specific feed backs and new researches. The impacts of these landslides can be mitigated or minimized, if the communities threatened by them, are forewarned about impending disaster and are prepared to face them.

There are no standard ready-made packages or systems for early warning but all the instrumentation, tools, equipment, observation and data processing systems are available in multiple choices. They are necessarily to be fashioned to suit a particular slope or a landslide according to its type, magnitude, hazard potential and the purpose of early warning alert. The hazard detection and early warning systems for different types of landslides are usually different. For example, planning for instrumentation and early warning for a pre-existing (repetitive) landslide will be different from the schemes for early warning against anticipated first time landslides. Likewise early warning schemes for mass movements such as a debris flow or a rock fall will be different from those for a block slide or a classical landslide with discrete boundary shears. The task of evolving early warning system in a given situation, will necessarily have to be assigned to experts.

An early warning is a process which involves three components:

Scientific & Technical Communities: These are responsible for studying and monitoring natural events to provide models, which can be used to forecast events in terms of intensity, time, and geographical span.
Government Authorities and Civil Agencies: These are responsible for establishing operations, frameworks related to preparedness and response in case of events.

Local Communities: The local communities must understand the nature of the hazards, their possible intensities and ranges, and react according to existing guidelines provided by the institutions identified by the authorities.

People-centered early warning systems empower the communities to prepare for and confront the fury of natural hazards. These bring safety, security and peace of mind to people. The effective early warning systems can provide resilience to natural hazards and protect economic assets and developmental gains.

A complete and effective early warning system comprises four inter-related elements:

- Risk knowledge: Prior knowledge of risk faced by communities.
- Monitoring and warning service: Technical and warning services for these risks.
- Dissemination and communication: Dissemination of easy to understand warnings to those at risk
- Response capability: Knowledge, awareness and preparedness to act

A weakness or failure in any one of them could result in failure of the entire system.

There is a notion among non-professionals that early warning systems for slope failures and landslides are always sophisticated and expensive. The fact however is that in many situations, simple, inexpensive and easily perceptible or measurable indicators can provide premonition of an impending slope failure. Monitoring of rainfall, surface and subsurface slope movements, slope subsidence, slope heave, development and widening of cracks, tilting of trees and poles, sudden oozing out of water or drying of water springs, sub slope piping, under slope erosion, sudden fall of boulders, cracking of building floors etc. often provide irrefutable evidence of unsatisfactory slope behaviour. Randomly picked isolated observations of this kind do not convey much but when all such evidence are collected, analysed and synthesized, early warning alerts do not remain a fantasy.

Simple devices commonly used for early warning against landslides in the past are (1) wire or special switches, actuated by the pressure of moving debris
Landslides Instrumentation, Monitoring and Warning

coupled to a decision-support system that release early warning alerts (2) electrical switch poles - which turn to an upright position upon displacement (3) photo-electrical barriers, especially for a rapidly moving debris flow or earth flow (4) pulsed radar for snow avalanches (5) fiber optic sensors and technology (6) acoustic emission technology (7) auto-actuated photographic systems and (7) GPS observations.

While the capabilities exist at global level to identify areas of occurrence of landslides, the capability of predicting as when these would occur is still developing. The signs of impending landslide can often be detected at an early stage and used for warning the affected communities. The time of landslide occurrence is possible to predict provided the slopes are monitored continuously. Advances in monitoring technology, particularly in real time transmission of information have helped in developing the technique of short-term prediction. More examples of same are rare. Best instance of this is an early warning system established for Yangtze River valley in China that monitors using 70 stations employing over 300 professionals. The network protects a population of 300,000 and so far has forecast 217 landslides and avoided estimated economic losses of US$ 27 million.

Remote sensing, the Global Positioning System (GPS), and Geographic Information Systems (GIS) are now mature and robust technologies that can be used to monitor landslides and landslide prone areas with greater accuracy than could be accomplished previously with field reconnaissance alone. Recent studies that have used these tools, including high-resolution satellite imagery, light detection and ranging (lidar). High resolution imagery and topographic mapping can lead to improved understanding of landslide mechanics and hazard prediction. Continued research into methods of data collection, processing, and synthesis is needed to realize the full promise of these technologies for global use in the coming decades.

Radar is one of the outputs of technological advances that can be used in monitoring the landslide effectively. Radar can be used for monitoring of avalanche movement, detection of crevasses, measuring the thickness of snow on the roads to facilitate their clearance and aiding search of avalanche victims.

Recent developments in remote sensing of weather information have provided the capability for more timely and spatially accurate assessments and warnings of weather-related hazards. Remote sensing of rainfall using Doppler Radar and Infrared Satellite sensing (DrISS) can provide information on rainfall with a spatial and temporal resolution that is potentially useful for near real-time
landslide hazard assessment and warning. Thresholds of rainfall intensity and duration for triggering of landslides have been developed for many regions worldwide using ground-based rainfall measurements and documentation of landslides. Rainfall thresholds have been applied for regional real-time landslide warning system. However, techniques for analyzing the temporal variation in slope stability on a local scale during the course of a storm with interval rainfall input are being developed now. The automatic weather station developed by ISRO can also be deployed in remote areas for collecting meteorological details and transmitting them through the different networks like VSAT, VPN etc.

A great majority of dormant landslides often turn active and become catastrophic during monsoon seasons and high intensity short duration rainfall events. The short term observation on rainfall is enough to underscore the importance of reliable and continuous rainfall measurements and real time analyses of rainfall data and should be arranged preferably at all major landslide sites. Rainfall information will be utilized for developing indicators for landslide alert especially for high landslide hazard areas prone to high intensity short duration rainfalls. For example, the eastern Himalayan region gets very heavy monsoon rainfall punctuated with occasional cloud bursts where the rainfall intensities are in the range of 300mm to 1000 mm/day (the more the intensity, the lesser is its duration). One study developed on this observation in 1980s led to linking of landsliding with the corresponding rainfall event coefficient (ratio of the rainfall of an event to the mean annual rainfall at the location). The findings revealed that event coefficients exceeding 20 % will trigger heavy landslide at all times. Very high probability of landslides was projected where event coefficients are10-20%. The probability of landslides was rated very low when the event coefficient fell below 5 %. The above inference is suggestive of the nature of advanced studies to be undertaken. It is important to encourage such studies and make them more scientific and systematic. Statistical correlation between rainfall and corresponding slope surface, subsurface movements, development of pore water pressure measurements within the slope, provide good insight into the slope behaviour.

Early warning thresholds for a well studied seasonal (repetitive) rain-induced landslide on discrete boundary shears with known pore pressure variations on the slide boundaries are extremely reliable. Such early warning thresholds usually take advantage of the unique, linear relationship between factor of safety (in terms of effective stress) and the pore water pressure (considered in terms of ratio). Since inter-relationships between rainfall intensity, slope surface and sub slope movements and pore pressures provide powerful means for reliable landslide forecasting, studies for these will be encouraged. Rainfall
Landslides Instrumentation, Monitoring and Warning

and the associated slope behavioural information will be utilized for developing indicators for landslide alert especially for high landslide hazard areas known to succumb to high intensity short duration rainfalls. In cases where no such information is available, a warning of a general nature and low reliability may still be possible through study of rainfall records in the backdrop of the previous landslide history.

Prediction of landslides is possible and research and development work on it deserves to be encouraged. Attempts to predict landslides have so far been based on time-dependent displacement behaviour of slides, generally in the tertiary stage of tertiary creep. Increasing availability of high-resolution geospatial maps and powerful slope instrumentation techniques can make real-time prediction of landslides possible.

Based on available information inputs when a decision for early warning is taken, the early warning dissemination strategy will be same as the one prescribed for other disasters. Operations such as post early warning interfacing with communities, press and media are common to all types of disasters. Integrated early warning dissemination systems will be evolved.

Even with the best of early warning systems, results will still be catastrophic if early warning signals are not properly interpreted and communities are not educated and trained on how to respond to the early warning alerts in real time. There should be an easily understandable manual clearly bringing out what is to be done when an early warning system flashes such an alert. Quite often the early warning alert may be lost in panic and confusion, if people are not aware of the response that must follow such alerts.

Studies are being carried out in many countries to establish the correlation between the intensity of rainfall and initiation of slides in different regions. Once threshold values of rainfall which will initiate landslide in a particular area, same can be the basis to issue early warning if the amount of rainfall in that particular area can be forecast. The correlations can be established with the help of past records as well as recent monitoring. In our country, IMD and NCMRWF are believed to have developed the capability to forecast the amount of rainfall an area is likely to receive 3-5 days in advance. Collaborative efforts in this field should be pushed. Depending on the success of this study, some more landslide prone areas may be selected for developing the early warning system.

Public response to a forecast is another difficult area. If the people are not educated, they may interpret the same forecast differently. If not fully aware of the lethal consequences, they will generally take warnings lightly. Disaster education must eliminate such possibilities.
6.9 Dissemination and Communication

Dissemination and communication mechanisms, as far as early warning systems are concerned, must be operational, robust and available round the clock. These should be designed to the needs of a wide range of threats for user communities. The dissemination of the information must be based on clear protocols and procedures and supported by an adequate telecommunication infrastructure. At the national level, effective dissemination and communication mechanisms are required to ensure timely dissemination of information to the authorities and communities at risk even in the most remote areas of the country. Each area may require different technological infrastructure to allow effective dissemination of messages. To ensure that all systems work smoothly in tandem, they will be based on internationally agreed standards.

At the national level, the effectiveness of warnings depends on their timely and effective dissemination to all at risk, not only through operational telecommunication systems but also through non-technical social networks. The latter is very important in poor communities that lack technologically advanced communication systems. Effective dissemination requires the establishment of a chain of command, in advance, in order to manage warning issuance and dissemination and ensure that the information is understood by those who need it and reaches all affected locations in the country. It is all the more important in case of landslides as they are localized events and can occur in remote locations.

A typical warning dissemination chain involves channeling warnings from technical and scientific sources through government decision makers and the media to multiple receivers who may also function as onward disseminators. Such users include emergency services, security agencies, operators of utilities, information and communication services, other economic service providers, NGO’s, voluntary agencies and vulnerable communities. In a system with integrated disaster management structures, the principal agencies responsible for issuing warnings and the processes for their issuance will be established by prior agreement. Various players are involved in generating warnings, including those in private sectors as in developed countries and civil defence in others. To be effective, early warning activities must cover all relevant areas in the country equally. In order to reach all those who need to take action, there is a need to design warnings for particular groups of stakeholders, such as different language groups, people with disabilities, and tourists. Public broadcast media remains the most widely used mode worldwide. The better systems for warning dissemination are those which are used in daily life and with which the users are most familiar. The role of community-based and grassroots organisations, as well as NGOs and other players, in disseminating warnings are pivotal.
Fig. 6.1: Inclinometer used for monitoring subsurface displacement

Fig. 6.2: Inclinometer installed to identify depth of slip surface

Fig. 6.3: Differential settlement Gauge for monitoring vertical movement

Fig. 6.4: Piped Wire Extensometer for measuring slope displacement

Fig. 6.5: Geodetic surveying for studying spatial movements in slopes

Fig. 6.6: Crack meter to study crack propagation and extension
Fig. 6.7: Water Level Indicator

Fig. 6.8: Peg markers used for monitoring slope movements

Fig. 6.9: Total station with GPS and Prisms for slope monitoring

Fig. 6.10: Slope stability radar

Fig. 6.11: Total Station, GPS and Prisms

Fig. 6.12: Hand held GPS and Total Station
Fig. 6.13: Reflecting stickers used to monitor surficial slope displacements

Fig. 6.14: Permanent station used to monitor movement using peg markers

Fig. 6.15: Solar panels used for power supply in automated monitoring system

Fig. 6.16: An automated landslide monitoring with recording system

Fig. 6.17: Remote Realtime Automated Monitoring System for landslide

Fig. 6.18: Video Camera and Landslide Alert system with power backup
7.1 Landslide Remediation Practices

A comprehensive risk management strategy requires systematic approach in planning and implementing concepts and measures. The risk management comprises pre-disaster prevention strategies and post-disaster management. The pre-disaster strategies include assessment of the hazard, analysis of risk through documentation of existing events, hazard zonation mapping and application of modern techniques that can help in preventing the activation of dangerous process. Comprehensive Hazard Zonation aims at preventing settlements, infrastructural elements to be located in vulnerable areas and also prescribing, to some extent, the appropriate treatment measures required at vulnerable locations.

Remediation practices, including slope geometry correction, providing protection at the toe of slope by retaining structures, management of the surface and subsurface water including development of pore pressures, nailing, bolting, anchoring, micropiling, application of geo-grids and geo-textiles and afforestation, constitute powerful elements of most geotechnical packages commonly used for improving stability of problematic slopes and landslides in India.

In our country, most landslides occur during the monsoon period barring a few which owe their origin to earthquake. Pore water pressure plays a major role in initiating landslide events. There are also instances where toe erosion by rivers or nalas and scouring of hill slope due to high velocity discharge of streams descending from the crown of the landslide gives rise to debris flow/slide. Hence, surface and sub-surface water management on the slopes or in the catchments is the most effective remediation measure for many landslides. Management of surface runoff and subsurface water is done through the development of drainage networks. Subsurface drainage management is hardly practiced in our country for stabilization of landslides. This aspect of landslide stabilization calls for immediate attention and the agencies like BRO, PWDs etc. engaged in slope stabilization activities must be well equipped with the modern technology to construct subsurface drainage network.

Reinforcing technologies like nailing, bolting, anchoring and tie back have provided apt solutions to bewildering varieties of civil and mining engineering
Landslides Remediation

problems. Numerous successful examples of stabilization of problematic slopes, landslides, open cast mines, tunnels, road cuttings etc., bear ample testimony to the great potential, the reinforcing technologies hold.

It is however, somewhat disappointing that the technological interventions in many cases have not always been quite sensitive to the real needs of the specific sites. There have been very little technological innovations in the area of landslide control in India. Research and development in the technological interventions by some knowledge based institutions or organizations in our country may be the only answer to overcome these shortcomings.

Already distressed slopes require immediate remediation. Landslides can be triggered by various factors like excessive rainfall, earthquakes and interference by man. Besides shallow erosion or reduction of shear strength caused by seasonal rainfall, the anthropogenic activities such as adding excessive weight above the slope, carrying excavations on the slope or at the foot of the slope resulting from developmental activities contribute towards large scale occurrence of landslide. However, some times different factors combine together to generate instability and in many cases these appear after some time. Many a times, it is not possible to reconstruct the evolution of the landslide process except in cases where site is well-instrumented. It may also be mentioned that it is nearly impossible to stabilise a failed slope until its morphology is well understood, causes responsible for inducing instability determined and the resultant risk assessed, analysed and adequately addressed. This can be achieved through detailed geological and geotechnical investigations. Therefore, it is necessary to conduct detailed investigations for planning remediation measures, as the extent and nature of stabilisation to be implemented will depend mainly on the results of the detailed investigations carried out at the affected site.

Depending upon the nature and purpose of work, degree of risk, cost effectiveness of remediation measures, the slope stabilisation methods generally include works involving modifications of the natural conditions of landslides such as topography, geology, ground water, and others that indirectly control portions of the landslide. These include drainage control works, soil/debris removal works, buttress fill works and river training works.

The drainage works comprise surface and sub-surface drainage works. The surface drainage control works are implemented to minimize the infiltration of rain water that builds up pore pressure. The surface drainage control works include drainage collection works and drainage channel works. The surface
drainage measures comprising lined catch water drain above the crown of a slide, lined contour drain on different levels of the slide mass, lined cascading chute drain are provided to intercept and divert rain water from the upslope and slide surface and to reduce infiltration and development of pore water pressure substantially. The purpose of the subsurface drainage control works is to remove the ground water within the landslide mass. The subsurface drainage control works include shallow and deep subsurface drainage control works depending up on the nature of the slide. The sub-surface drainage works may include intercept under drains, interceptor trench drains, horizontal gravity drains, drainage wells and drainage tunnels.

Soil/ debris removal works comprise these treatment measures that yield most reliable results and generally can be expected to be very effective in respect of small to medium sized landslides. The soil/ debris removal or offloading of the slide mass is generally undertaken from the crown portion downwards and depending on the properties of the material, benches or berms are created at appropriate intervals.

In case of fill works, buttress fill is placed at the lower portions of the landslide as counterweight to the landslide mass. It is very effective if the removed soil is used.

Scouring and erosion of channel bank or toe of a slope reduce the stability of the slope and often tends to induce slide activity. In such cases, check dams and bank protection can be erected to prevent further erosion. If required, deflection spurs are provided on the upstream of affected slope.

Provisions of restraining structures rely directly on the construction of structural elements with a view to improve the stability of sliding mass. These include pile works that act as keys to tie together the moving landslide and the stable ground to restrain the movement, the anchors and bolt works utilise the tensile force of anchor bodies embedded through the slide mass and into stable earth and construction of retaining and breast walls to prevent small and secondary landslides that often occur along the toe portion of larger landslides.

Once treatment measures have been implemented on a landslide, the treated slopes are required to be protected against the effects of atmospheric elements like rain, snowfall etc. This requires minimizing direct exposure of the treated slope to the atmospheric agencies and can be achieved by providing a protective covering to the treated slope. The common practice is afforestation that not only provides effective covering to the slopes but also improves the shear
strength of the material through network of plant roots. Vegetation can also be directly used to help stabilize slopes using biotechnical methods, commonly referred to as slope bio-engineering. These methods, originally pioneered in Europe, involve aggressive planting of carefully selected varieties and the construction of engineered structures using live materials whose strength will increase in time. Vegetation can also be effective on steep slopes, where it intercepts precipitation and reduces both runoff and excessive infiltration.

Shotcreting with or without a chain link fabric wire-mesh is very effective in protecting slopes with weathered rocks. Drainage holes can be provided along with shotcreting. Covering the slope surface with geo-fabrics made of natural as well as synthetic material is also commonly used in slope protection works.

**Table 7.1: A brief list of landslide remedial measures**

<table>
<thead>
<tr>
<th>A modification of Slope Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Removing material from the area driving the landslide (with possible substitution by lightweight fill)</td>
</tr>
<tr>
<td>• Adding material to the area maintaining stability (counterweight berm or fill)</td>
</tr>
<tr>
<td>• Reducing general slope angle</td>
</tr>
<tr>
<td>• Slope stitching using timber or cement concrete (Figs. 7.1, 7.2 &amp; 7.18)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B Drainage</th>
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</thead>
<tbody>
<tr>
<td>• Surface drains (Figs. 7.13 to 7.15) to divert water from flowing into the slide area (collecting ditches and pipes); Example French Drains (Fig. 7.53)</td>
</tr>
<tr>
<td>• Shallow or deep trench drains filled with free draining geo-materials (coarse granular fills and geo-synthetics)</td>
</tr>
<tr>
<td>• Buttress counterforts of coarse grained materials (hydrological effect)</td>
</tr>
<tr>
<td>• Vertical (small diameter) boreholes with pumping or self draining</td>
</tr>
<tr>
<td>• Vertical (large diameter) wells with gravity draining</td>
</tr>
<tr>
<td>• Sub-horizontal or sub-vertical boreholes</td>
</tr>
<tr>
<td>• Drainage tunnels, galleries or adits</td>
</tr>
<tr>
<td>• Vacuum dewatering</td>
</tr>
<tr>
<td>• Drainage by siphoning</td>
</tr>
<tr>
<td>• Electro-osmotic dewatering</td>
</tr>
<tr>
<td>• Vegetation planting (hydrological effect)</td>
</tr>
</tbody>
</table>
C Retaining /Restraining Structures

- Gravity retaining walls
- Crib block walls (Fig. 7.18)
- Gabion walls
- Passive piles, piers and caissons
- Cast in situ reinforced concrete walls
- Reinforced earth retaining structures with strip/sheet polymer/metallic reinforcement elements/geosynthetic and geotextiles (Figs. 7.3, 7.4, 7.6, 7.44 & 7.45)
- Buttress counterforts of coarse grained material (mechanical effect)
- Retention nets/meshes for rock slope faces
- Rock fall attenuation or stopping systems (rock trap ditches, benches, fences and walls)
- Protective rock/concrete block against erosion
- Drum Diaphragm Wall or Tyre Walls

D Internal Slope Reinforcement

- Rock bolts
- Micropiles
- Soil nailing
- Anchors (prestressed or not)
- Grouting
- Stone or lime/cement columns
- Heat treatment
- Freezing
- Electro-osmotic anchors
- Biotechnical measures like planting vetiver grass or using jute/coir mats
- Mulching

7.2 Mass Improvement Techniques

The stabilisation of hill slopes can be achieved by improving the mechanical characteristics of the potentially unstable ground. It has the following two different approaches:

- Insertion of reinforcement elements in the ground
- Improvement of the mechanical characteristics of the ground through chemical, thermal or mechanical treatment
In measures for slope protection, the reinforcement technology has found wide application. This can be achieved by installation of large diameter wells supported by one or more crowns of consolidated and possibly reinforced earth columns, anchors, networks of micro piles, nailing and grouting with cement or chemical grouting depending upon the properties of the material.

The improvement of mechanical characteristics of the ground can also be achieved through thermal treatment of potentially unstable hillsides made up of clayey materials or by using electro-osmotic treatment in case of homogenous clayey ground.

7.3 Mitigations methods for various types of landslide hazards

The simplest means of dealing with landslides is to avoid construction on steep slopes and existing landslides. However, this is not always practical. Regulating land use and development to ensure that construction does not reduce slope stability is another approach. In cases where landslides affect existing structures or cannot be avoided, physical controls can be used. In some cases, monitoring and warning systems allow residents to evacuate temporarily during times when the probability of landslide activity is high.

7.3.1 Physical Mitigation Methods for Slides & Slumps

1. Drainage
   a. Surface drainage (Figs. 7.13 to 7.16)
      i. Ditches
      ii. Regrading (Fig.7.59)
      iii. Surface /crack sealing (Fig.7.48)
   b. Subsurface drainage
      i. Horizontal drains (Figs.7.7 & 7.8)
      ii. Vertical drains/Wells (Figs.7.11 & 7.12)
      iii. Trench drains/interceptors, cut-off drains/counterforts (Fig.7.10)
      iv. Drainage galleries or tunnels (Fig.7.9)
      v. Blanket drains
      vi. Electro-osmosis
      vii. Blasting
      viii. subsurface barriers

2. Excavation or Regrading of Slope
   a. Total removal of landslide mass
   b. Regrading of slope
c. Excavation to unload the upper part of landslide
d. Excavation and replacement of the toe with other material

3. **Restraining Structures**
   a. Retaining walls (Figs. 7.19, 7.20, 7.23, 7.25 to 7.30)
   b. Piles
   c. Buttresses and counterweight fills (Fig. 7.19)
   d. Tie rods and anchors (Fig. 7.57)
   e. Rock bolts/anchors/dowels

4. **Vegetation (Fig. 7.60)**

5. **Soil Hardening**
   a. Chemical treatment
   b. Freezing
   c. Thermal treatment
   d. Grouting

### 7.3.1.1 Site leveling

Smoothening the topography of slide surface can prevent surface water from ponding or connecting with the ground water. Any depressions on the slope that might retain stagnant water must be removed. Infilling and sealing large cracks in the soil surface by grading the soil mass are beneficial and prevent surface water from reaching the failure plane.

### 7.3.1.2 Drainage Techniques

Ground water is the most important single contributor to landslide initiation and its continuation. Not surprisingly, therefore, controlling drainage is the most effective element of slope stabilization scheme, for both existing and potential landslides. Drainage is effective because it increases the stability of the soil and reduces the weight of the sliding mass. Drainage can be either surface or subsurface. Surface drainage measures require minimal design and costs and have substantial stability benefits. They are recommended on any potential or existing slide.

The two objectives of surface drainage are to prevent erosion of the face, reducing the potential for surface slumping, and to prevent infiltration of water into the soil, thereby reducing ground-water pressures. Subsurface drainage also is effective but can be relatively expensive. It is therefore essential that ground water be identified as a cause of the slide before subsurface methods are developed. The various methods of drainage are:
7.3.1.3 Ditches and drains

Surface drainage can be either through surface ditches or shallow subsurface drains. Surface drainage is especially important at the head of the slide, where a system of cutoff ditches that cross the headwall of the slide, and lateral drains to lead runoff around the edge of the slide are effective. Ditch gradient should be at least 2 percent, to ensure rapid flow away from the unstable area.

The simplest type of subsurface drain is the lateral trench constructed above an unstable slope. Drainage trenches are economical only for shallow soils overlying bedrock or hard impermeable till. The trenches should be excavated up to the base of the shallow soil to intercept any ground-water flow along the failure plane. They are backfilled with coarse gravel to prevent sloughing of the ditch sidewalls. It is more useful if drainpipes are now and then backfilled with coarse gravel.

7.3.1.4 Drainpipes

Horizontal drainpipe is a widely used measure for landslide prevention in highway construction. It is most effective when installed during initial excavation. Because of the long lag times in lowering of ground-water tables, the drains are effective only if the pipe is carefully installed, failure surface intersected, and the pipe actually drains the soil. As most slopes have varying soil and hydraulic and geometric conditions, drainage systems must be individually designed. After drilling has been done up to the desired depth and the casing installed, the latter is cleared of soil, and sections of slotted PVC drainpipe are covered with filter cloth, and pushed into the casing and coupled together. The casing is then withdrawn and screen is installed over the end of the drain. Drain holes must be thoroughly cleaned of drill cuttings and mud. Uncleaned holes may be only 25 percent effective.

In clay soils, the full change in ground-water tables can take up to 5 years, with 50 percent improvement taking place in the first year. Once water tables are lowered in clay soils, the change is fairly permanent; however, seasonal fluctuations can occur: rainfall will not alter the ground-water level in the slope provided the drains do not clog. In sandy soils, the water table will lower within a few months, but will fluctuate with rainfall.

7.3.1.5 Straw wattles and straw bales

Straw wattles, also known as straw worms, bio-logs, straw noodles, or straw tubes, are fabricated cylinders of compressed, weed-free straw
Sub-Module 7

Training Programme on COMPREHENSIVE LANDSLIDES RISK MANAGEMENT

(wheat or rice), 20 to 30 centimeters in diameter and 7 to 9 meters long. They are encased in jute, nylon, or other photodegradable materials and have an average weight of 16 kilograms. They are installed in a shallow trench forming a continuous barrier along the contour (across the slope) to intercept water running down a slope. Straw wattles should be effective for a period of 1 to 2 years if they can be installed on slopes up to 70 percent; however, their effect diminishes greatly on slopes steeper than 50 percent. Soils can be shallow but not less than about 8 inches. Straw wattles increase infiltration, add roughness, reduce erosion, and add short-term protection on slopes where permanent vegetation will be established to provide long-term erosion control. Straw bales, easily obtainable in most areas of the world, are portable, and have a modular-type application for slope erosion and drainage control.

7.3.1.6 Retaining Walls

For all types of retaining walls, adequate drainage through the structure is essential because very high ground-water pressure can build up behind any retaining wall, leading to its failure. Drainage can be provided simply with a coarse backfill and foundation material.

7.3.1.6.1 Timber crib

Timber crib walls (Fig.7.18) are box structures built of interlocking logs and backfilled with coarse aggregate. They work by intersecting the critical sliding surface, thus forcing the potential failure surface to a deeper, less critical depth. The structure must be able to withstand: (1) shearing, (2) overturning, and (3) sliding at the base. It must, therefore, be strongly built by burying to sufficient depth and extending beyond the critical failure plane. Crib walls are only effective where the volume of soil to be stabilized is relatively small. They are most efficient where a thin layer of unstable soil overlies a deeper, more stable layer of soil. Crib wall structures’ volume should be 10 to 15 percent of that of the soil to be stabilized. This relatively small volume provides little counterweight support at the toe; therefore, virtually the entire resistance to failure comes from the strength of the crib.

7.3.1.6.2 Steel bin wall

A steel bin wall is made from corrugated galvanized steel components bolted together to form a box and then filled with earth. The stability of a gravity wall is due to the weight of the wall itself, perhaps aided by the weight of soil
in front of the wall. The bulk of the weight is from the contained soil, not the steel, and this should be kept in mind when the foundation is prepared. Large walls must be individually engineered, with load and foundation requirements calculated. Structural and civil engineering design charts provide stringer (horizontal member) specifications and height-to-width ratios for typical loading conditions. The widths of walls vary from 2 to 5 meters and are one-half to three-fifths the height of the wall. To provide additional sliding resistance, the foot of the wall is usually 0.5 to 1.0 meter below grade, although the design should not rely on the additional toe support, as it can erode or be removed inadvertently. The factor of safety is improved if the wall is at a 1:6 slope. Fill material must be well drained and compacted, preferably in 20-centimeter lifts. Material behind the wall also should be well drained and moderately compacted.

7.3.1.6.3 Reinforced earth wall

Reinforced earth is a patented system for constructing fills at very steep angles to vertical without the use of supporting structures at the face of the fill. The system uses horizontal layers of flexible metal strips within the fill to form a composite earth-metal system with high strength.

7.3.1.6.4 Gabion walls

Gabions are wire mesh, boxlike containers filled with cobble-sized rock that are 10 to 20 centimeters size. A gabion retaining wall (Figs.7.13, 7.25 & 7.28) can also be constructed from stacked gabions. Gabion walls usually are inexpensive and are simple and quick to construct. Due to their flexibility, they can withstand foundation movement, and they do not require elaborate foundation preparation. Because of their coarse fill, they are very permeable and thus provide excellent drainage. Gabion walls work because the friction between the individual gabion rows is very high, as is the friction between the basal row and the soil underneath. When failure occurs, it is almost always in the foundation soil itself. Three-tiered walls up to 2.5 meters high can usually be constructed without consulting any detailed engineering analysis. Higher walls are very heavy by nature due to their added bulk and need larger base foundations and possibly counterforts for bracing of the wall. (A counterfort is a buttress bonded to the rear of walls, and is designed to improve stability). Gabion walls built on clay soils require counterforts, which can be constructed as gabion headers extending from the front of the wall to beyond the slip circle. The counterforts serve both as structural components
and as drains. Design charts are available for various combinations of hillslope angle and retaining-wall height.

### 7.3.1.7 Piles

Large-diameter piles can be placed into the toe of a slope to form a closely spaced vertical pile wall. Pile walls are normally used as a pre-excavation restraint system—the cut slope excavation takes place in front. Whereas large-diameter concrete pile and culvert pile walls have been used successfully on highways, wood or steel piles that are small in diameter are not. For most earth or rock movement, wood piles are not adequate to provide enough shearing resistance. They are suitable only where the volume of soil to be stabilized is small. On average, one wood pile is necessary for every 50 cubic meters of soil, which is not sufficient for large stabilization projects. Too few piles can result in toppling and (or) breakage by the moving mass of soil, as well as by soil movement between the piles.

A major limitation when log piles are used is depth, as many failure surfaces lie below the height of the piles. Wood piles are the best for treating shallow soil failures over deeper stable soils. The piles should extend well below the potential failure surface and be firmly driven into firm subsoil. If the depth of placement is not sufficient to allow the piles to act as a cantilever system, then the piles must be tied back with an additional anchor system.

### 7.3.2 Debris-Flow Mitigation

This section describes some simple mitigation methods for debris-flow hazards for homeowners, business plans, and others. A short section on erosion and fire control is also included since erosion, fire, and subsequent debris flows and flooding are interrelated hazards.

**Physical Mitigation Methods for Debris Flows and Debris Avalanches**

1. **Source-Area Stabilisation**
   a. Check Dams (Fig.7.17)
   b. Revegetation
2. **Energy Dissipation and Flow Control**
   a. Check Dams (Fig.7.42)
   b. Deflection Walls
   c. Debris Basins (Fig.7.40)
3. Direct Protection
   a. Impact spreading walls
   b. Stem walls
   c. Vegetation barriers

7.3.2.1 Check Dams

These are small, sediment-storage structures built in the channels of steep gullies to stabilize their bed. They are commonly used in Europe and Japan to control channelized debris-flow frequency and volume. A less common use of check dams is to control raveling and shallow slides in the source area of debris slides. Check dams are expensive to construct and therefore are usually built only where important installations or wildlife habitat, such as a camp or unique spawning area, lie downslope. Channelized debris flows are associated with channel gradients over 25 degrees and obtain most of their volume by scouring the channel bed. Check dams serve three main purposes when installed in the channels:

- mitigate the incidence of failure by reducing the channel gradient in the upper channel.
- reduce the volume of channel-stored material by preventing downcutting of the channel with subsequent gully sidewall destabilization and by providing toe support to the gully slopes.
- store debris-flow sediment, when installed in the lower part of the channel.

When installed on debris slides, the dams store raveled material, which eventually creates small terraces on the slide, reducing the surface slope. Check dams can be constructed of reinforced concrete or of log cribs. Concrete mortared rock dams do not usually exceed 8 m in height, whereas log crib dams must not exceed 2 m. The spacing of dams depends on channel gradient and dam height. For example, a 2-m high dam in a 20-degree channel with 10-degree sloping channel infill will be spaced every 12 m. Lateral stream erosion and scour by spillway water are the main drawbacks.

How to prevent check dam failure
During construction, the concrete wing walls and log crib ends must be tied securely into the canyon wall and streambed to withstand backfill pressures and lateral scour. Wing walls should slope at about 70 percent and extend a minimum of 1-2 meters into the banks. The foundation of the dam should have a minimum width of one-third the total height of the dam and be deeper than any scour holes likely to develop.

Backfilling the dam, rather than allowing it to fill naturally, reduces the dynamic loading on the structure and results in a more stable design. The slope of the backfill should be less than one-half the channel gradient. Dams that have been back-filled will usually survive a debris flow; the backfill material will not be scoured during or after a torrent.

**7.3.2.2 Strengthening Slopes for Erosion/Debris Flows**

Erosion may cause the steepening and lengthening of gullies and resulting in loosening of soil, plants, rocks, and boulders, which can intensify the effects of debris flows. Keeping an area free of excess fuel for fires can also help in the mitigation of debris flows, as burnt slopes become more vulnerable to the effects of debris-flow initiation and erosion. Loss of vegetation that holds soil in place and physical and chemical changes to the soil that result from intense heat and burning by fires make this soil more prone to debris flows.

**7.3.2.3 Debris-flow basins**

These catchment basins are commonly built at the base of slopes where debris flows are frequent. They are used especially in areas where the debris must be contained so that soil and debris are stopped from flowing into sensitive ocean or river shorelines areas or where there are structures at the base of the slope that are vulnerable to debris-flow damage. These basins will eventually fill with the debris-flow deposits and must be emptied periodically or they will overflow. Commonly, heavy duty dump trucks and power shovels are needed to empty the debris and carry it away. However, small basins can be emptied manually. They should be designed to be able to contain the maximum flow volumes of an area to prevent overtopping during a flow event.

**7.3.2.4 Debris Flow Retaining Walls**

These structures can be of various materials. They are designed to stop the accumulation of debris, either by blocking its flow or diverting it around the vulnerable area. These structures should be carefully designed as any deflection of material may be unintentionally redirected to additional vulnerable areas.
7.3.3 Rock Slope Stabilization/Mitigation Techniques

Rockfalls range from a few fist-sized rocks to large cliff sections and boulders which, depending on size and shape, can roll, bounce, and careen down slopes, landing in areas at great distances from the fall lines. Recreation areas such as beaches near cliffs, parks, and open spaces may be affected by rockfall, and people are frequently exposed to these hazards. People venturing too near the edges of cliffs and rocky slopes can add pressure to already weak overhangs and cause rockfalls to land on people below or sustain injuries themselves on these collapsing edges. Whether hiking, camping, walking, or working around cliffs or rock faces, people encounter the hazard many times without warning. A variety of engineering techniques can be implemented to help mitigate the effects of rockfalls, and some of these are discussed here. In some cases, more than one type of engineered solution is the best.

Physical Mitigation Methods for Rockfalls

1. Stabilisation
   a. Excavation
   b. Benching
   c. Scaling and trimming
   d. Rock bolts/anchors/dowels (Figs. 7.31 to 7.36 & 7.57)
   e. Chains and cables (Fig.7.46)
   f. Anchored mesh nets (Fig.7.21)
   g. Shotcrete (Fig.7.43)
   h. Buttresses
   i. Dentition

2. Protection
   a. Rock-trap ditches
   b. Catch nets and fences (Fig.7.49)
   c. Catch walls
   d. Rock sheds or tunnels (Figs.7.37 & 7.39)

7.3.3.1 Excavation of Rock / Benches

Horizontal benches excavated into a rock face are among the most effective protection measures for rockfall. In addition to intercepting rockfall, benches reduce tensional forces in the surface rock and reduce surface erosion rates.
They also reduce the rate of occurrence of rockfall. However, they have little or no effect on potential deep-seated rock failure. Bench faces can be constructed steeper than the overall slope angle, as rocks that fall are likely to remain on them. Vertical bench-face angles should be avoided, as tension cracks, dangerous overhangs, and excessive rockfall can result. The placing of bench faces should be stopped at the base of weaker rock layers, fractured rock zones, or water-bearing zones. A minimum width of 4 m is recommended for the benches, and all benches should have drainage ditches to divert water away from the slope.

7.3.3.2 Scaling and Trimming

Loose, unstable, and (or) overhanging blocks of rock, which may pose danger to passing traffic and (or) pedestrians, can be removed by scaling or trimming. Scaling is the removal of loose blocks by the use of hand-held pry bars and small explosive charges. Trimming involves drilling and light blasting by explosives, followed by scaling, to remove larger areas of overhanging or potentially dangerous rock. Scaling and trimming can be reduced by controlled blasting, but it is not always feasible. Overhanging rock is either removed or trimmed back to a stable part of the face. Scaling operations are usually carried out by workers suspended by ropes or other means, using pry bars, jacks, and explosives. These can be time-consuming and expensive (sometimes dangerous) and on active slopes may need to be repeated, say every few years, or as need has to be. Scaling is highly skilled work and can sometimes be dangerous; scaling crews should be trained and the work performed by professionals.

7.3.3.3 Shotcrete and Gunite

Shotcrete and gunite are types of concrete that are applied by air jet directly onto the surface of an unstable rock face. Shotcrete is an all-inclusive term to describe spraying of concrete or mortar either by dry- or wet-mix process. Gunite refers only to the dry-mix process in which the dry cementitious mixture is blown through a hose to the nozzle, where the water is injected immediately before application. This is a rapid and relatively uncomplicated method commonly used to provide surface reinforcement between blocks of rock and also to reduce weathering and surface scaling. Shotcrete contains aggregate up to 2 cm in size and is more commonly used than gunite, which uses smaller aggregate. Both materials can be applied rapidly by air jet so that large areas can be covered in a short time.
7.3.3.4 Anchors, Bolts, and Dowels

These are tools composed of steel rods or cables that reinforce and tie together a rock face to improve its stability. Anchors are post-tensioned members used to support large blocks of rock, whereas bolts are shorter and support surface rock. Dowels are similar to bolts but are not post-tensioned. Reinforcing a rock slope with steel requires a specialist’s knowledge of rock stability analysis, of grouting techniques, and of testing procedures. Determination of orientation of the potential failure surfaces is crucial to a successful anchor system and requires considerable engineering experience.

7.3.3.5 Safe Catching Techniques

7.3.3.5.1 Catch Ditches

Wide catch ditches are effective in containing rockfall, but these must be designed taking into account the cliff geometry taken into account, and it is advised to consult a professional about specifications. The bottom of the catchment ditch should be covered with loose earth to prevent falling rock from bouncing or shattering into pieces or shards. If there is not enough space to construct as wide a ditch as is specified, then a combination of smaller ditches with a gabion or rock wall along their downhill edges can be used.

7.3.3.5.2 Cable, Mesh, Fencing, and Rock Curtains

Cable lashing and wire nets are simple, low-cost methods for protecting a road or path from rockfall. For large, unstable blocks, strands of metal cable are wrapped around the blocks and anchored to the slope. Where the rock is too fractured to be restrained by individual cables, cable nets are used. Wire mesh (closely spaced interwoven wires) can be used to prevent smaller rocks, less than 0.75 meter in size, from falling. The standard mesh is double-twisted gabion wire mesh or a heavy gage metal chain link. The mesh is either loosely draped over a uniform rock face or bolted or otherwise firmly secured where the cliff face is irregular and the mesh cannot make close contact with the rock. Bolting the mesh to the rock face can prevent rock from becoming dislodged and provides overall stability of the slope or rock face. Wire mesh also is useful on steep soil cuts, especially beneath talus slopes.

Catch nets made of cable and wire mesh can be constructed to catch falling rock at the bottom of gullies and slopes. When suspended from an anchored
cable, the mesh forms a flexible barrier to dissipate the energy of the falling rock and will usually stop boulders up to one meter in diameter, if properly secured. Additionally, catch nets can be used in conjunction with roadside catch ditches.

Rock fences are fairly easy to install and can restrain small rocks from falling onto roads but do not stop rocks that bounce out over the top of the fence barrier. Rock curtains are more effective in directing rocks down to a catch ditch or other catching structure, by preventing them from bouncing outward onto the highway or structures below.

7.3.3.6 Retaining Walls

Retaining walls can work much like those described for soil slope-stabilization techniques in keeping rockfall debris out of an area. They are similar to rockfall fences but are in most cases more substantial and stronger. Retaining walls can be made out of steel, concrete, timbers, or other materials and must be anchored properly so as not to tip over during rockfalls.

7.3.3.7 Rock Sheds/Shelters (Figs.7.50)

These sheds / shelters are built over roads, railways, and sometimes structures to shield the area from rockfall and rock avalanches. Shed structures are either open ended or completely envelope the rockfall area completely in a concrete or steel (or other material) structure that will deflect rockfall away from the road, railway, or structure.

7.3.3.8 Rock Ledge Reinforcement (Fig.7.54)

These are not commonly used because they work only for unique situations and must be carefully engineered and should be structurally strong.

7.4 Slope Stabilization using vegetation

Seeding with grasses and legumes, reduces surface erosion, which can under certain conditions lead to landslides. Plating with shrubs adds vegetative cover and stronger root systems, which in turn enhance slope stability. If not controlled, surface erosion and small, shallow failures can lead to larger problems that cannot be controlled. The terms “Bionegineering” and “biotechnical” slope stabilization refers to use of vegetation as slope protection to arrest and prevent slope failure.
Planning is required for the successful implementation of a revegetation program. Before undertaking seeding, a person with local experience should be consulted. Local knowledge based on successes and failures of projects is invaluable. Seed application should begin immediately following a disturbance, at a minimum of approximately 6 weeks before periods of drought or damaging frost. Controlling surface water drainage, removing cut-bank overhangs, reducing slope angles, and benching all should be done before seeding.

7.5 Mulching

Mulch (Fig.7.51) is nonliving material spread over soil surface to provide protection from surface erosion by rain and retention of soil moisture. Various types of mulches will work - straw, grass or wood fibres, seaweed, and paper products.

7.6 Biotechnical slope protection

This is used to reduce the environmental consequences of landslide mitigation measures. The conventional earth retaining structures made of steel or concrete usually are not pleasing or environment friendly. These traditional hard remedial measures are increasingly being supplanted by vegetated composite soil/structure bodies that are environmentally more friendly. Common biotechnical systems include geonets anchored by soil nails that hold in place soil seeded with grass and geocells with seeded soils in the interstices.

Research has been done on using plants to stabilize soils to mitigate landslides. One of the most promising types of plants is Vetiver (Fig.7.60), a type of grass that works very well in many different environments, to stabilize slopes. It provides a practical and inexpensive way to minimize landslides.

Biotechnical slope protection consist of 2 elements - biotechnical stabilization and bio-engineering stabilization, both of which entail the use of live materials - specifically biotechnical vegetation stabilization uses mechanical elements (structures) in combination with biological elements (plants) to prevent and arrest slope failures. Mechanical and biological elements must function together in a complimentary manner.

7.6.1 Bio-Engineering Measures for Stabilization of Surficial Landslides

Bio-engineering can be defined as the use of live plants or plant parts in the controlling soil erosion and mass movement, to fulfill engineering functions.
The living plant materials are used as the main structural components or reinforcements in the soil mantle. It provides immediate reinforcement and secondary stabilization occurs as a result of adventitious roots that develop along the length of the buried stems. Finally, vegetation that is seeded or planted provides mechanical and hydrological support to the soil.

Bio-engineering if employed carefully, can prevent minor problems transforming into larger, complex ones. Vegetation affects the surficial stability of slopes in significant ways. The stabilizing or protective benefits of vegetation depend both on the types of vegetation and slope degradation processes. In case of mass stability, the protective benefits of woody vegetation range from mechanical reinforcement and restraint by the roots and stems to modification of slope hydrology as a result of soil moisture extraction via evapo-transpiration.

- Catching material that is moving down a slope
- Armouring the slope against surface erosion from runoff and splash
- Supporting the slope by propping from the base
- Reinforcing the soil by increasing shear strength
- Draining a slope depending on the pattern and density of the vegetation
- Limiting the extent of slope failure by binding soil
- Improving the soil and micro-catchments, thus promoting regeneration

Bio-engineering is often a part of broad design, in conjunction with a number of standard civil engineering measures. These include check dams, prop walls, toe walls, wire bolsters, jute netting etc. However, it is stressed that bio-engineering should always be used as part of the overall design in resolving a particular slope problem. It must always be integrated in such a way that it complements and enhances other measures. Vegetation as a key component in off-road engineering is also environmentally sound and is practical application of several environmental mitigation measures. In the hilly regions, roads are an inseparable part of the slopes that they cross and they must be fully integrated into this landscape if they are to remain sustainable. Bio-engineering techniques offer the best way of blending roads with the landscape and limiting damage to surrounding agricultural, horticultural and forest land. They allow the restoration of the original vegetation and ecosystem, and particularly of tipping sites and spoil disposal.
areas. Through both implementation and later productivity, they offer social and economic benefits for poor rural farmers.

### 7.7 Landslide Dam Mitigation

As previously mentioned, flooding is the primary hazard from landslide dams when a it fails, or flooding occurs when it is overtopped by the ongoing flow of water accumulated behind the dam. The following measures can be implemented when communities are faced with potential hazards from landslide dams:

- **Diversion of inflow water before it reaches the lake formed by the landslide dam**

  This can be done by diverting water from the stream into upstream reservoirs or irrigation systems. Although usually only a temporary measure, diversion may slow the filling of the lake to allow the application of a more long-term solution.

- **Temporary drainage from the impoundment by pumps or siphons**

  The rising water level can be controlled temporarily by means of pumps or siphons, causing the water to flow over the low point of the dam. This is usually a short-term (less than 1 to 2 years) measure that provides time for more extensive, long-term solutions.

- **Construction of an erosion-resistant spillway**

  The most common method of stabilizing a landslide dam is to construct an erosion-resistant open-channel spillway either across the dam or an adjacent abutment. When the overtopping by water occurs, flow is controlled by the spillway in much the same way that emergency spillways are constructed on engineered dams to control water level. An additional advantage of this type of spillway is that it allows for the lowering of the water level behind the dam, which helps in reducing the upstream flooding that landslide dams may cause.

  Spillways are not always successful in preventing dam breaching and downstream flooding; they sometimes fail due to retrogressive erosion (erosion from the spillway outlet to its intake) caused by high-velocity outlet flow. To prevent erosion by minimizing flow velocity, the spillway should be wide and shallow. If possible, it should be lined with erosion-resistant materials (commonly riprap), especially at the outlet. Often, check dams are
installed along steeper grades of the spillway to prevent erosion. Spillways that fail due to erosion may have been partially successful because they limit the total volume of the water behind the dam, thus reducing total discharge even if the dam breaches entirely.

Open-channel spillways across the landslide dam commonly are excavated by bulldozers; however, draglines, backhoes, explosives, and hand labor all have been used. Excavation can be dangerous in rough terrain, so an access road has to be constructed.

7.9 Drainage tunnel through an abutment (Fig.7.38)

A long-term method of preventing overtopping and breaching of a landslide dam is construction of a diversion tunnel through an adjacent dam abutment. Because large landslide dams commonly occur in mountain canyons, they usually have bedrock abutments; thus rock-tunneling methods are commonly used. The landslide may be left as it is, as it is too massive to remove. However, it may be monitored with instrumentation.
Fig. 7.1: Spraying crib works for preventing surficial failures

Fig. 7.2: Spraying crib wo for preventing surficial failures

Fig. 7.3: Application of Geosynthetic mats for slope stability

Fig. 7.4: Geosynthetic Grids used for slope protection and vegetative growth

Fig. 7.5: Jute mats used for slope stabilization and vegetative growth

Fig. 7.6: Slope protection with geogrid helps prevent surficial rock failures
Fig. 7.7: Flexible drain pipe system used to dispose off water responsible for triggering and promoting landslide.

Fig. 7.8: PVC pipes to drain out water from unstable slopes.

Fig. 7.9: Drainage Gallery / Tunnels to collect and dispose off subsurface water.

Fig. 7.10: Underground pipes collect sub-surface water from landslide site.

Fig. 7.11: Covered well for subsurface drainage.

Fig. 7.12: Open well for collecting subsurface water from landslide site.
Fig. 7.13: Boulder Gabion wall with surficial drainage system

Fig. 7.14: Surface lined drains to dispose off water properly

Fig. 7.15: Arch type wall structure and drainage system used for stabilizing slopes

Fig. 7.16: Well lined surface drains at landslide site

Fig. 7.17: Debris Control Structures and Mechanism

Fig. 7.18 Timber stitching for preventing slope failure
Fig. 7.19: Sand bags used as retaining structures for reducing landslide impact

Fig. 7.20: Block masonry retaining wall with weep holes

Fig. 7.21: Net fencing to hinder rockfall movement on downside

Fig. 7.22: Multiple remedial measures for stabilizing landslide site

Fig. 7.23: Empty bitumen drums filled with debris acting as retaining wall

Fig. 7.24: Wire crated shotcreting
Fig. 7.25: Gabion wall made of boulders and wire baskets

Fig. 7.26: Boulder masonry walls with joints to adjust minor deformations

Fig. 7.27: Banded Random Boulder wall without masonry

Fig. 7.28: Random Boulder Gabion Wall with wire crates

Fig. 7.29: Random Rubble Boulder Masonry Wall

Fig. 7.30: Stone masonry wall with weep holes and drain pipe
Fig. 7.31: Nailing for slope reinforcement

Fig. 7.32: Steel anchors and mesh used as preventive measure

Fig. 7.33: Multi-bar reinforcement with an instrument to record wall pressure

Fig. 7.34: Rock bolting and shotcreting for slope stabilization

Fig. 7.35: Rock anchors with tie beams made of reinforced concrete

Fig. 7.36: Rock bolting for slope reinforcement
Fig. 7.37: Tunnel to avert recurring and chronic landslide

Fig. 7.38: Snow Gallery to avoid avalanches and debris flows along roads and facilitate traffic movement

Fig. 7.39: Tin Roof sheds to prevent direct impact of rock fall

Fig. 7.40: Debris Catch Traps to avoid impact of debris flows

Fig. 7.41: Fencing with metallic nets and girdles for saving roads, vehicles and passerbyes from the landslides

Fig. 7.42: Boulder wall barriers to arrest falling boulders and reduce impact of debris flows
Fig. 7.43: Shotcreting with wire mesh and weep holes

Fig. 7.44: Geosynthetic sheets used for stabilizing slopes

Fig. 7.45: Application of geosynthetics for slope stabilization

Fig. 7.46: Chain and cable type ring nets for preventing rock / boulder fall

Fig. 7.47: Drum wall for mitigating landslide

Fig. 7.48: Sealing of cracks with pervious materials beneath the surface and impervious material on top
Fig. 7.49: Catch nets for restraining rock fall

Fig. 7.50: An open rock shed

Fig. 7.51: Rice husk drains (Source: USGS)

Fig. 7.52: Trespassing rock slide area

Fig. 7.53: French drains

Fig. 7.54: A reinforced rock ledge
Fig. 7.55: Polythene sheets used to prevent water percolation

Fig. 7.56: Net Fencing to avoid the impact of sliding on road and traffic

Fig. 7.57: Rock Bolting

Fig. 7.58: Rockfall blocking road

Fig. 7.59: Benching, retaining structures, drainage and plantation

Fig. 7.60: Vetiver plantation for slope stabilization
8.1 Standard Operating Procedures for Responding to Landslide Disasters

The world over it has been experienced that a prompt, well-coordinated and effective response mounted in the aftermath of disasters not only minimizes loss of life and property but also facilitates early recovery. The important ingredients of an effective response system are integrated institutional arrangements, state of the art forecasting and early warning systems, failsafe communication system, rapid evacuation of threatened communities, quick deployment of specialized response forces and coordination and synergy among various agencies at various levels in dealing with any disaster. Most importantly, all the agencies and their functionaries must clearly understand their roles and responsibilities and specific actions they have to take for responding to disaster or threatening disaster situations.
The objectives of the SOP are -

(a) To provide, in a concise and convenient form, a list of major executive actions involved in responding to natural disasters and necessary measures for preparedness, response and relief required to be taken;

(b) To ensure that all concerned Ministries, Departments and Organisations of the Government of India, State Governments and District Administrations know the precise measures required from them at each stage and also to ensure that all actions are closely and continuously coordinated; and

(c) To indicate various actions which would be required by the State Governments/UT Administrations within their sphere of responsibilities so that they may prepare and review the Contingency Action Plans accordingly.

The instructions contained in this SOP should not be regarded as exhaustive in terms of all the actions that might be considered necessary.

The SOP encompasses the following five phases of disaster management for effective and efficient response to natural disasters.

(i) Preparedness Phase - This will include taking all necessary measures for planning, capacity building and other preparedness so as to be in a state of readiness to respond, in the event of a natural disaster. This Stage will also include development of Search & Rescue Teams, mobilization of resources and taking measures in terms of equipping, providing training, conducting mock drills/exercises etc.

(ii) Early Warning Phase - This will include all necessary measures to provide timely, qualitative and quantitative warnings to the disaster managers to enable them to take preemptive measures for preventing loss of life and reducing loss/damage to the property. In the event of a natural disaster or imminent threat thereof, all the concerned agencies will be informed/notified for initiating immediate necessary follow up action.

(iii) Response Phase - This will include all necessary measures to provide immediate succor to the affected people by undertaking search, rescue and evacuation measures.

(iv) Relief Phase - This phase will include all necessary measures to provide immediate relief and succor to the affected people in terms of their essential needs of food, drinking water, health & hygiene, clothing, shelter,
(v) **Restoration Phase** - This will include all necessary measures to stabilize the situation and restore the utilities.

This SOP does not cover long-term measures needed either for mitigation or for rehabilitation/recovery of the affected people and reconstruction of the area.

### 8.2 Emergency Operations Centre (EOC)

The EOCs/Control Rooms at National, State and District levels will be the nerve centres for coordination and management of disasters. The objectives of the EOCs shall be to provide centralized direction and control of any or all of the following functions:

- Receive and process disaster alerts and warnings from nodal agencies and other sources and communicate the same to all designated authorities
- Monitor emergency operations
- Facilitate Coordination among primary and secondary ESF Ministry/Departments/Agencies.
- Requisitioning additional resources during the disaster phase
- Issuing disaster/incident specific information and instructions specific to all concerned
- Consolidation, analysis, and dissemination of damage, loss and needs assessment data
- Forwarding of consolidated reports to all designated authorities

#### 8.2.1 Location of EOC

The EOC will be set up at a suitable location and the building should be disaster resistant so as to withstand the impact of disasters and remain functional during the emergency phase.

#### 8.2.2 Communication Network of EOCs

Under the National Communication Plan being implemented by the Government of India, the EOCs at all the three levels shall have a fail proof communication network with triple redundancy of NICNET of NIC, POLNET of Police and SPACENET of ISRO in addition to the terrestrial and satellite based communication to ensure voice, data and video transfer. Under the network, the EOCs/Control Rooms of all the States will be directly connected with the NEOC/Control Room of MHA at the National level. The district EOCs/Control Rooms will be connected with
the respective State EOCs/Control Room. All these control rooms will function on 24x7 basis and will be functional round the year. Suitable personnel will be selected and imparted training in the operation of Control Rooms will be posted to man these EOCs/Control Rooms.

8.3 National Disaster Response Force (NDRF)
For the purpose of specialized response to disasters/ emergencies both natural and manmade NDRF has been constituted comprising of 10 battalions drawn from Central Para-Military Forces. Each NDRF battalion has 18 Specialized Search & Rescue Teams including doctors, paramedics and dog squad.

The general direction and control of NDRF is vested with NDMA while the command and supervision of the Force is vested in Director General of Civil Defence and NDRF appointed by the Central Government.

8.3.1 State Disaster Response Force (SDRF)
State Governments/SDMAs shall be primarily responsible for taking preparedness measures and building response capacity as per their vulnerability to various natural disasters and constitute State Disaster Response Forces on the pattern of NDRF.

8.4 National Disaster Mitigation Resource Centres (NDMRCs)
The NDMRCs will be co-located with the NDRF battalions. These will also serve as repositories for NDMR bricks of relief stores for the disaster affected people, in each of the 10 NDRF locations. These will cater to the emergent requirements especially for the first 72-96 hours. These stores will supplement the reserves maintained by the respective states/UTs.

In addition, these centres will assist in running mock drills and capacity development programmes. During disasters, they will act as facilitators to the states/UTs in deployment of central resources and provide much needed additional link to the centre.

8.4.1 State Disaster Mitigation Resource Centres (SDRMCs)
The State Governments shall also set up Resource Centres based on their requirements to pre-position essential supplies. The States shall be responsible to constantly evaluate their own capabilities to handle that situation and project the anticipated requirements for the central resources well in time. Memorandum of Understanding may be entered into by the neighboring States for assisting each other during natural calamity. Inter-State assistance and cooperation shall be encouraged.
8.5 Other Disaster Response Services/Organisations
In addition to NDRF at national level and SDRF at state levels, the provisions have been made to strength the Five and Emergency Services as well as Civil Defence to reduce the deployment of armed forces during the disaster times.

8.5.1 Fire & Emergency Services
The Fire Services in the States/ UTs will be strengthened and will be made multi-hazard response units. These will be appropriately equipped depending upon their location and area of operation.

8.5.2 Civil Defence
Civil Defence volunteers will be enrolled for voluntary services in accordance with the provisions of the Civil Defence Act. The services of CD volunteers should be utilized during response to natural disasters. Civil Defence training institutions at the National and State levels will be set up/upgraded to cater to the training of Civil Defence volunteers in relevant areas of disaster response.

8.5.3 Armed Forces
Establishment of NDRF should progressively reduce deployment of the Armed Forces, which would be deployed only when the situation is beyond the coping capacity of State Government and NDRF.

8.5.4 Emergency Support Functions (ESFs)
Disaster response is a multi-agency function. There will be one Lead or Primary Agency which will be responsible for managing and coordinating the response while other agencies will support and provide assistance in managing the incident. Each ESF will be headed by a lead Ministry /organisation responsible for coordinating the delivery of goods and services to the disaster area, and is supported by numerous other organizations. These ESFs will form integral part of the Emergency Operation Centres (EOCs) and each ESF should coordinate its activities from the allocated EOC. Extension teams and workers of each ESF will be required to coordinate the response procedures at the disaster affected site.

8.6 Pre-Contract for Essential Commodities
All the State Governments will ensure storage and availability of essential commodities including medicine in the vulnerable districts well before the onset of monsoon and cyclone periods. They will also enter into pre-contract with the suppliers of essential commodities, medicines, tents, boats etc. on an annual basis for supply of these items at pre-decided rates within a stipulated time framework.
8.7 District Level Preparedness for Response

8.7.1 Vulnerability assessment
Each district will make its vulnerability assessment and identify potential hazards. While making such assessment, the risk involved and capacity to respond will be taken into account. The local community will be informed about their vulnerability to potential hazard/disasters through the representatives of Panchayati Raj Institutions/Local Self-Government and NGOs.

8.7.2 Contact Details
A comprehensive directory of officers involved in disaster management at various levels will be prepared for National and State levels giving their names, addresses, telephone, fax and mobile numbers, email address. Such a directory will be widely circulated and updated periodically.

8.7.3 Review
Annual review of the preparedness measures will be done at the National, State, District and sub-Divisional levels. Annual review will ensure that all loose ends are tied up so that response during natural disasters is efficient, effective and timely. The review will also include rearrangements for essential commodities required for response and relief and emergent basis. The decentralization of authority is an important feature of good management of natural disasters. As such, the States will also review their resources and preparedness in their annual meetings, the present levels of delegation of powers to the Relief Commissioners, Additional Relief Commissioners and District Magistrates.

8.7.4 Mock Drills
Search and Rescue Teams at the National and State Levels will carry out mock drills on various disasters situation annually. For floods and cyclones, these will be carried before the monsoon and cyclone period, tentatively in March and September for cyclones and June for floods. For earthquakes, landslides etc., such drills can be done in the month of March itself. At the district and State levels, mock exercises will be carried out for testing the effectiveness of all the preparedness machinery including manpower and equipment.

8.8 Resource Inventory - IDRN
Government of India has launched India Disaster Resource Network (IDRN), which is a web enabled resource inventory for disaster management. The
state Governments will ensure that necessary entries have been made in the Web-portal and updated at-least once in a month by the designated district authorities.

8.9 National Crisis Management Committee (NCMC)

1. On direction of the Cabinet Secretary, meeting of the NCMC shall be convened
2. NCMC will take stock of the situation
3. It shall give necessary directions to NEC, MHA, other Central Ministries/ Departments/ Agencies and State Governments

8.10 National Executive Committee (NEC)

1. JS(DM), MHA shall take order from Union Home Secretary for convening the meeting of NEC
2. NEC shall assess the situation and give directions to the concerned Ministries/Departments of the centre, the state governments and the State Disaster Management Authorities regarding measures to be taken by them in response to any specific threatening disaster situation or disaster
3. NEC shall coordinate response of various agencies
4. It shall depute a team of Officials to visit the affected States for on the spot assessment of the situation and coordinate with State Governments
5. It shall mobilize resources and dispatch them to concerned States
6. It shall monitor and review the situation on a regular basis

8.11 Role of the Nodal and Other Central Ministries/ Departments

1. On activation of national ESF Plan, the concerned Ministry/Department shall depute the designated officials to NEOC for coordination of response measures
2. Ministries/Departments shall coordinate with their counterparts and make assessment of immediate needs in their respective sectors
3. Ministries/Departments shall provide resources both in terms of men and material for assistance of the States on request of NEC


8.12 State Level

Following shall be the sequence of action at the State level:

8.12.1 SEOC shall discharge the following functions:

1. On receipt of information either from NEOC/DEOC or from Early Warning Agencies or any other reliable sources, State Emergency Operation Centre, shall be activated fully as per laid down protocol

2. SEOC shall issue alerts/warning to all designated authorities at the State level and Districts including for Public Information to AIR/Doordarshan/Press

3. SEOC shall send First Information Report to NEOC, MHA and thereafter Daily Situation Report till situation normalizes

4. SEOC shall collect all relevant information and appraise the status to the designated decision making authorities

5. It shall arrange Meetings of SEC

6. It shall activate ESFs of State if the situation so warrants

8.12.2 State Disaster Management Authority (SDMA)

1. Meeting of the SDMA shall be convened on the direction of Chief Minister

2. SDMA will take stock of the situation

3. SDMA shall give necessary directions to SEC, Deptt. Of Disaster Management and other Departments/agencies of the State Government and concerned DDMAs.

4. SDMA shall decide on Inter-State assistance and cooperation

8.12.3 State Executive Committee (SEC)

1. Secretary (DM) shall convene the meeting of SEC

2. SEC shall assess the situation and give directions to the concerned Departments/agencies of the State Govt. and DDMAs concerned regarding measures to be taken by them in response to any specific threatening disaster situation or disaster

3. SEC shall coordinate response of various agencies

4. SEC shall requisition NDRF or Armed Forces if the situation so demands.

5. SEC may depute a team of Officials to visit the affected Districts for on
the spot assessment of the situation and supervise the response & relief measures.

6. SEC shall mobilize resources and dispatch them to concerned Districts

7. SEC shall monitor and review the situation on a regular basis

8. SEC shall keep the NEC and NDMA informed of the situation

9. SEC shall constantly evaluate their own capabilities to handle that situation and project the anticipated requirements for the central resources well in time

10. SEC shall deploy State level Incident Command Team on the request of the DDMA as and when required

11. In the event of calamity of severe nature, the SEC will consider appointment of Senior Officers, delegate powers and assign specific areas for timely and effective, efficient management of disasters

12. SEC will also take necessary steps to pool the resources for better management of crisis situation. This includes the pooling of food grains funds and other resources available in the districts under various Government schemes. However, these resources will be reimbursed to the respective schemes/Departments once the situation becomes normal

**8.12.4 Role of Other Departments/Agencies**

1. On activation of State ESF Plan, the concerned Department/Agency shall depute the designated officials to SEOC for coordination of response measures

2. Departments/Agencies shall coordinate with their National counterparts and mobilize central assistances, such as specialized manpower, equipments, materials etc. to meet immediate needs in their respective sectors

3. Departments/Agencies shall provide resources both in terms of men and material for assistance to the DDMAs

**8.13 District Level**

Following shall be the sequence of action at the District level:

**8.13.1 DEOC shall discharge the following functions:**

1. On receipt of information either from NEOC/SEOC or from Early Warning agencies or field functionaries from Sub-divisions, Blocks, Tehsils or any
other reliable sources, District Emergency Operation Centre shall be activated fully as per laid down protocol.

2. DEOC shall issue alerts/warning to all designated authorities at the District level

3. DEOC shall send First Information Report to SEOC and NEOC, MHA and thereafter Daily Situation Report till situation normalizes

4. DEOC shall collect all relevant information and appraise the status to the designated decision making authorities

5. DEOC shall maintain all records and documents related to the response

6. It shall activate ESFs of District if the situation so warrants

8.13.2 District Disaster Management Authority (DDMA)

1. DDMA shall assess the situation and give directions to the concerned Line Departments/Agencies at the District level regarding measures to be taken by them in response to any specific threatening disaster situation or disaster

2. DDMA shall take such other action as may be necessary for coordinated response to natural disasters. These may include the following:

   a. Assessing situations based on reports received from various sources and giving directions to different agencies for immediate response, relief and restoration of critical infrastructure

   b. Reviewing the resources and capacities of different agencies to deal with the situations and giving directions for pooling available manpower, equipments and resources available with different agencies for speedy and effective response

   c. Requisitioning assistance from NDRF/ Armed Forces/ other specialized agencies, if necessary

   d. Coordinating with civil society and Non-Governmental Organizations for supplementing the efforts of government agencies

   e. Monitoring and reviewing the situations on a regular basis

8.14 First Response

In disasters where there are no early warning signals available, the community members will be the first responder. However, immediate support and assistance shall be available from other important first responders like the police, State Disaster Response Force (SDRFs), Fire and Medical Services.
Other important responders will be the Civil Defence, Home Guards and youth organizations such as NCC, NSS and NYKS drawn from local units.

8.14.1 First Information Report

DEOC shall send First Information Report immediately to SEOC, NEOC and all designated authorities/agencies. FIR shall invariably give an account of the severity of the disaster, damage & loss caused, locally available capacities, priority. The FIR shall briefly summarize,

(i) Severity of the disaster
(ii) Actions being taken locally
(iii) Local coping capacities (including locally available resources)
(iv) Immediate priorities for external relief required and approximate quantities for the same
(v) Best logistic means for delivering relief
(vi) Forecast of possible future developments including new risks.

The First Information Report on occurrence of natural calamity shall be sent to SEOC, NEOC and MHA, Government of India within maximum 24 hours of occurrence of calamity.

8.14.2 Daily Situation Report

A standardized form for reporting of situation report on daily basis has been prepared for the District, State and National levels. This format will be used uniformly for all the States. The State Governments shall submit situation report to the MHA on six hourly basis during first three days thereafter daily till the situation come to normal.

8.14.3 Air dropping of food in inaccessible areas

Airdropping of food and essential commodities shall be undertaken in the inaccessible areas. The State Governments/ district authorities will liaise with Air Force Authorities and the NEC, Ministry of Home Affairs, Government of India for requisitioning the helicopters.

The agencies for preparing food packets for airdropping and items as well quantity to be included in the food packets will be communicated by the district administration in advance.
8.14.4 Rapid Damage Assessment

Rescue & relief operations shall be based on ground assessment of damage and losses. Preliminary assessment shall be carried out immediately within 24 hours for planning the response. Teams shall be constituted of officials drawn from various sectors to make assessment on the basis of on the spot visits, aerial surveys and information collected from primary and secondary sources.

8.14.5 Immediate repair of infrastructure

The Departments/Agencies of the State Governments responsible for various infrastructural facilities such as electricity, drinking water, telecommunication etc shall repair the damage caused by the disaster and will take immediate steps to restore damaged essential services so that rescue & relief operations are conducted smoothly.

8.14.6 Disposal of dead bodies

The State Government/District authorities shall earmark authorities responsible for disposal of bodies in event of mass causalities. The process of identification and handing over to next of kin shall be followed. Mass burial/disposal of bodies shall be done as a last resort. Local religious & cultural practices shall be honoured while disposing dead bodies

8.14.7 Disposal of carcasses

The State Government/District authorities shall earmark authorities responsible for disposal of carcasses in event of mass destruction. The process to be followed for mass disposal of carcasses shall be decided by Department of Animal Husbandry.

8.14.8 Information and Media Management

During disaster situations, the dissemination of accurate information through electronic and print media is very important. Regular press briefings shall be made by District Magistrate/Collector or his authorized representative at pre-designated time as a single source of information from Government.

8.14.9 Relief

In the aftermath of disasters the affected people must be looked after for their safety, security and the well being and provided food, water, shelter, clothing, medical care etc. so as to ensure that the affected people live with dignity. State Governments shall be responsible for providing prompt and adequate
relief assistance to the victims of disasters. The minimum standards of relief shall be laid down by the NDMA and by the SDMAs in terms of sections 12 and 19 respectively.

8.14.10 Food & Nutrition

People affected by disasters may be deprived of food and therefore food aid shall be provided to sustain life. The following measures shall be taken:

1. Where necessary free distributions of food shall be made to those who need the food most
2. The food distribution will be discontinued as soon as possible
3. Wherever possible dry rations shall be provided for home cooking
4. Community Kitchen for mass feeding shall be organised only for an initial short period following a major disaster particularly where affected people do not have the means to cook
5. While providing food assistance, local food practices shall be kept in mind and commodities being provided must be carefully chosen, in consultation with the affected population
6. Foods must be of good quality, safe to consume, and appropriate and acceptable to recipients.
7. Rations for general food distributions shall be adopted to bridge the gap between the affected population’s requirements and their own food resources
8. Food distributed should be of appropriate quality and fit for human consumption
9. Food should be stored, prepared and consumed in a safe and appropriate manner at both household and community levels
10. Food should be distributed in a responsive, transparent, equitable manner
11. NGOs, CBOs and other social organizations should be involved for supplementing the efforts of the Government
12. The nutritional needs of the population should be met and malnutrition and micronutrient deficiencies of identified at risk groups addressed

8.14.11 Water

Water supply is invariably affected in natural disasters. Safe drinking water might not be available particularly in hydro-meteorological disasters.
The following measures shall be taken by the State Governments/ district administration:

1. The State Governments shall identify alternative sources of water and make necessary arrangements for supply to the affected population.
2. The State Governments shall ensure that affected people have adequate facilities and supplies to collect, store and use sufficient quantities of water for drinking, cooking and personal hygiene.
3. It shall be ensured that drinking water supplied conforms to the prescribed quality standards.
4. It shall be ensured that water made available for personal and domestic hygiene should not cause any risk to health.

8.14.12 Health

During post disaster phase many factors increase the risk of diseases and epidemics. These include poverty, insecurity, overcrowding, inadequate quantity and quality of water, poor environmental and sanitary conditions, inadequate shelter and food supply.

8.14.13 Medical Response

Medical response has to be quick and effective. The execution of medical response plans and deployment of medical resources warrant special attention at the State and District level in most of the situations. The following measures shall be taken by the States/Districts:

1. A mechanism for quick identification of factors affecting the health of the affected people shall be established for surveillance and reporting.
2. An assessment of the health and nutritional status of the affected population shall be done by experts with experience of emergencies, if possible, local knowledge.
3. The voluntary deployment of the nearest medical resources to the disaster site, irrespective of the administrative boundaries, will be warranted.
4. Mobile medical hospitals and other resources available with the Central Government shall be provided to the States/UTs.
5. Adequate supply of medicines, disinfectants etc. shall be made.
6. Where necessary inoculation shall be done.
7. Vaccination of the children & pregnant women shall be undertaken.
8. Vector-borne diseases are a major cause of sickness and death in many disaster situations. Vector control measures shall be undertaken.

9. Water borne diseases may cause sickness and deaths and therefore adequate measures shall be taken to prevent such outbreaks.

8.14.14 Mental Health Services

Disasters cause tremendous mental trauma to the survivors. Psychosocial support and mental health services should be made available immediately in the aftermath of disaster so as to reduce the stress and trauma of the affected community and facilitate speedy recovery. The following measures shall be undertaken by States/UTs:

1. A Nodal Mental Health Officer shall be designated for each affected District
2. Rapid needs assessment of psycho-social support shall be carried out by the Nodal Officer/ Health Department
3. Trained man power for psycho-social and mental health services shall be mobilized and deputed for psycho-social first aid and transfer of critically ill persons to referral hospitals
4. Psycho-social first aid shall be given to the affected community/population by the trained community level workers and relief and rescue workers
5. Psycho-social first aid givers shall be sensitized to local, cultural, traditional and ethical values and practices
6. Psycho-social support and mental health Services shall be arranged in relief camps set-up in the post disaster phase
7. Where large numbers of disaster victims have to be provided psychosocial support a referral system for long term treatment shall be followed
8. The services of NGOs and CBOs may be requisitioned for providing psycho-social support and mental health services to the survivors of the disasters
9. Community practices such as mass prayers, religious discourse etc. should be organized with four preventive and promotive mental health services

8.14.15 Clothings & Utensils

During disasters, people lose their clothings and utensils. The following measures shall be taken by State/District authorities:
1. The people affected by the disaster shall be provided with sufficient clothings, blankets etc. to ensure their dignity, safety and well-being.

2. Each disaster-affected household shall be provided with cooking and eating utensils.

8.14.16 Shelter

In a major disaster a large number of people are rendered homeless. In such situations shelter becomes a critical factor for survival of the affected people in the initial stages of a disaster. Further, shelter becomes essential for safety and security and for protection from the adverse climatic conditions.

Shelter is also important for human dignity and for sustaining family and community life in difficult circumstances. The following measures shall be taken by State/District authorities for providing shelter to the affected people:

1. Disaster affected people who have lost their dwelling units or where such units have been rendered damaged/useless shall be provided sufficient covered space for shelter.

2. Disaster affected households shall be provided access to appropriate means artificial lighting to ensure personal security.

3. Disaster-affected households shall be provided with necessary tools, equipment and materials for repair, reconstruction and maintenance for safe use of their shelter.

8.14.16 Relief Camp

The following steps shall be taken for setting up relief camps in the affected areas:

1. Adequate numbers of buildings or open space shall be identified where relief camps can be set up during emergency.

2. The use of premises of educational institutions for setting up relief camps shall be discouraged.

3. One member of the Incident Command Team of the district trained in running and management of relief camps will be deputed for management of relief camps.

4. The requirements for operation of relief camps shall be worked out in detail in advance.

5. Agencies to supply the necessary stores will be identified in the pre-disaster phase.
6. The temporary relief camps will have adequate provision of drinking water and bathing, sanitation and essential health-care facilities

7. Adequate security arrangements shall be made by local police

8. Adequate lighting arrangements shall be made in the Camp Area including at water points, toilets and other common areas

9. Wherever feasible, special task forces from amongst the disaster affected families will be set up to explore the possibility of provision of food through community kitchens, provision of education through the restoration of schools and anganwadis

10. Efficient governance systems like entitlement cards, identification cards, bank accounts for cash transfers etc. shall be developed

8.14.17 Sanitation and Hygiene
Sanitation services are crucial to prevent an outbreak of epidemics in post disaster phase. Therefore a constant monitoring of any such possibilities will be necessary. It should be ensured that disaster-affected households have access to sufficient hygiene measures. Soaps, detergents, sanitary napkins and other sanitary items should be made available to ensure personal hygiene, health, dignity and well-being. In the relief camps, toilets should be sited, designed, constructed and maintained in such a way as to be comfortable, hygienic and safe to use

8.14.18 Provision of Intermediate Shelters
In the case of devastating disasters, where extreme weather conditions can be life-threatening or when the period of stay in temporary shelters is likely to be long and uncertain, the construction of intermediate shelters with suitable sanitary facilities will be undertaken to ensure a reasonable quality of life to the affected people. Such shelters shall be designed to be cost effective and as per local needs.

8.14.19 Management of Relief Supplies
Speedy supplies of relief materials shall be ensured in relief operations. A supply chain management system shall be developed. Standard Protocols shall be put in place for ensuring the procurement, packaging, transportation, storage and distribution of relief items. A mechanism shall be developed for receiving donations in cash or kind and their distribution.

8.14.20 Transparency in Relief
SDMAs/DDMAs shall take all appropriate measures for transparency in the relief operations. Affected people shall be apprised of the nature and quantum of
relief admissible to them. Proper formats will be developed to acknowledge the receipt of relief materials and their further distribution.

8.15 Landslide Alerts and Warnings

Geological Survey of India issues alerts and warnings to all designated authorities and agencies of the Central Government and State Governments/ district Administration for landslides in the following categories.

**Category IV**: Landslides of small dimensions that occur away from habitations and do not affect either humans or their possessions. These may occur near infrastructural installations, agricultural and forestlands and may not affect them in a significant manner. These slides may include small incidents that block communication routes for short periods or do not affect the society in a significant manner. - Yellow

**Category III**: Landslides which are fairly large and affect infrastructural installations like strategic and important highways and roads, rail routes and other civil installations like various appurtenant structures of hydroelectric and irrigation projects. The landslides that enter large water bodies like reservoirs of hydroelectric projects and could damage some of components of these projects. - Orange

**Category II**: The landslides that may occur on the fringes of inhabited areas and result in limited loss of life and property. Landslides, which result in blockade of courses of relatively smaller natural drainages. If the blockade is of relatively smaller dimensions its impact would be of a lower order. Although a threat potential is there, it may not be immediate. - Orange

**Category I**: Landslides of large dimensions that are located over or in close vicinity of inhabited areas like urban settlements or fairly large rural settlements. Activity on these slides can result in loss of human lives, dwellings on large scale. These slides may also inflict heavy losses on urban infrastructure. The slides that block busy pilgrimage routes during peak times resulting in hardships to thousands of pilgrims and sometimes resulting in loss of human life. Landslides which result in blockade of courses of relatively large natural drainages. If the blockade is fairly large it could lead to formation of a very large reservoir of water behind it. Formation of a large landslide dam could result in sudden flooding of areas located upstream. Abrupt breaching of landslide dam would suddenly release enormous quantities of water in the downstream areas leading to flash floods that could result in loss of life and damage to property on large scale. - RED
8.16 FORMAT FOR FIRST INFORMATION REPORT ON OCCURRENCE OF NATURAL CALAMITY

(To be sent to MHA, Government of India within maximum of 24 hours of occurrence of calamity)

From: State --------------- Date of Report ---------------

To

JS (DM), MHA (fax: ______; email: ______)

I/c National Integrated Operations Centre, MHA (fax: ______; email: ______)

a. Nature of Calamity
b. Date and time of occurrence
c. Affected area (number and names of affected districts)
d. Population affected (approx.)
e. Number of Persons
   □ Dead
   □ Missing
   □ Injured
f. Animals
g. Affected
h. Lost
i. Crops affected and area (approx.)
j. Number of houses damaged
k. Damage to public property
l. Relief measures undertaken in brief
m. Immediate response & relief assistance required and the best logistical means of delivering that relief from State/National
n. Forecast of possible future developments including new risks.
o. Any other relevant information
Response to Landslide Disasters

Fig. 8.2: Fire Guards and Civil Defence personnel extricating a dead body

Fig. 8.3: Community volunteers searching and recovering buried bodies

Fig. 8.4: Bull dozer clearing landslide debris from the road

Fig. 8.5: Fire Guards and Civil Defence personnel extricating a dead body

Fig. 8.6: Labour and Bull dozer kept for clearing debris, buried by the landslide

Fig. 8.7: People and livestock under heavy mass of rock debris
Fig. 8.8: Steep and negative slopes - a challenge to landslide managers

Fig. 8.9: JCB clearing debris

Fig. 8.10: Bull dozer for clearing road

Fig. 8.11: JCB and Loader used in removing and disposing landslide debris

Fig. 8.12: Community workers rescuing children buried under landslide

Fig. 8.13: First responders helping landslide victims
Training Programme on COMPREHENSIVE LANDSLIDES RISK MANAGEMENT

Response to Landslide Disasters

Fig. 8.14: Tree logs being used to make temporary bridge in landslide affected area

Fig. 8.15: Searching for buried people in bad weather conditions

Fig. 8.16: Mechanical breaking and removal of big boulders

Fig. 8.17: Bulldozer clearing landslide debris from road side

Fig. 8.18: Failure of retaining structures due to weak foundation

Fig. 8.19: Inspecting the damage by landslide in a residential area
Fig. 8.20: Community and Civil Defence acting together in search and rescue

Fig. 8.21: Removing debris and searching children buried underneath

Fig. 8.22: People trying to trespass a landslide

Fig. 8.23: First Aid Vehicle (108) for assisting disaster victims

Fig. 8.24: Road washed off by landslide makes access difficult for rescue & relief

Fig. 8.25: Rescuers helping people cross a damaged bridge and road
Response to Landslide Disasters

Fig. 8.26: Political leaders visiting landslide affected area

Fig. 8.27: Politicians along with officials from administration visiting a landslide affected site

Fig. 8.28: Supply by water tanks after water pipe line got disrupted by a landslide

Fig. 8.29: Local people assisting in disposal of dead bodies

Fig. 8.30: Canine search for locating human bodies under landslide debris

Fig. 8.31: People face shortage of gas and fuel supply due to road disruption by landslide
8.17 Rapid Damage and Loss Assessment

Disaster brings in its wake damages to life, property, infrastructure, economy and environment. For adequate and effective response to disasters, it is of paramount importance to assess the extent of physical harm to assets, property and infrastructure which render them less valuable or less effective.

The objective of Rapid Assessment is to determine the precise nature and extent of damage so that Rescue and Relief measures are undertaken in the affected area. The rapid damage assessment has the following major components:

(i) Geographical area impacted
(ii) Structural damage to buildings, housing stocks, establishment etc.
(iii) Damage to roads & bridges, public buildings shops, workshops, stalls etc.
(v) Damage to water supply lines, electricity supply lines, public utilities etc.
(vi) Damage to agricultural crops, livestock, etc.

Tools for Rapid Assessment
Arial surveys
Photographs, video graphs / films of the affected area
Satellite imageries
Field reports
TV/Press coverage
Visual Inspection Checklist
Camera
Laptop
Notebook
GIS Map
GPS
Compass
Charging apparatus and electric supply for camera, GPS, laptop etc.
Response to Landslide Disasters

**8.18 Proforma for Rapid Damage Assessment Report (Radar) of a Landslide**

Date of Survey:--------------Time:-------------- (Hrs)-------------- Venue:----------
State---------- District---------- Block---------- Tehsil---------- Village----------

A. **Event Details**: Geographic Location (Longitude, Latitude, Altitude) -
   Event Type (Slide/Flow/Fall/Subsidence) –
   Landslide Dimensions (Length, Width & Depth in meters)
   Magnitude of Disaster (Scale & Level)-
   Response (Community/Agency)-
   Chronology of events - (Time of Initiation, Period/Duration of activity, Sequence of activity, cause of disaster and consequences as well as response); Association with impacts of any other hazard like earthquake, thunderstorm, lightning, flashfloods etc., if any should be mentioned
Total Number of Villages/Towns/ Cities Affected in the surveyed area:
Total Population Affected (males/females/children):
Number of Families Affected:

B. **Impacts on Life**
Humans:  Deaths (Male/Female/Children/Physically or Mentally impaired)-
   Injured   Buried/Missing -
   Homeless - Orphans (male/female) -
Livetocks (Cows/Goats/Sheep/Hens & Chickens/Mules etc.):  Deaths - Injured

C. **Impacts on Buildings / Structures**:  
Residential Buildings:  Destroyed - Damaged (kind & extent of damages) -
Cow-Pens/Animal Sheds:  Destroyed - Damaged (kind & extent of damage)-
Governmental/Community Buildings (Temples/Community Halls/Educational & Health Buildings):  Destroyed - Damaged (kind & extent) -
Commercial Buildings (Offices/Shops/Industries):
   Destroyed - Damaged (kind & extent of damage)-

D. **Landscape Changes / Ground Failures / Environmental Impacts**:  
Agricultural Land Damaged (m²) -  Housing Plots Damaged (m²) -
Drainage Disruption (River/Channel blockade) -  Ground Cracks (Dimensions-LxWxD)-
Forest Land affected (no. & types of trees)-
Any other ground changes like river blockade, riverbed upliftment, water pollution etc.-
E. Impacts on Infra-structure:
Transportation (Vehicles/Roads/Bridle path/Bridges/Footpath) -
Communication (Wireless/Phone/Mobile/Internet /Pager) -
Drinking Water Supply - Power Supply -
Sewerage and Sanitation -

F. Projects/Activities affected: Hydel / Power-
Grain Grinders (Gharats)-Other Projects-
Socio-cultural - Economic/Livelihood-

G. Total Losses (Approx.): Tangible (in rupees)-
Intangible (in brief description)-

H. Additional Information:

Name & Signatures of the Survey Team with designation & duties performed
Team Leader (Overall Damage Assessment)
JE/AE, PWD (assessed buildings/structures) AE/JE, Irrigation (Infra-structures)
District Geologist (ground failures)  Section Officer, Revenue (Impacts on life)

Note: A local map, hand-held GPS, measuring tape, digital camera, RDAR Proforma and notebook with a pen, pencil & eraser should be carried by the team and data/information may be fed in excel sheet after completion at the NIC Office for use by various authorities and public dissemination on a web portal.

Photos/Sketches / Maps showing extent and distribution of damages
Note: North and scale may be marked on the map
8.19 Search and Rescue Skills

Searching and Locating: A set of techniques and procedures, the purpose of which is to obtain a response or indication of the presence of live victims within a landslide.

Composition of Search Team: A squad leader with 5 or more rescuers.

Squad Leader: is responsible for developing the search plan, diagrams, documentation and making recommendations to the Incident Commander.

Rescuers: carry out the search operation physically and as outlined by the squad leader.

Basic Tools: Probing Radar, Radio equipment to communicate with team members and Command Post, Walkie Talkie, Work site marking supplies, Flags, Cones etc.

Warning and alert devices: Megaphone, Whistle, Hammer, Flags, Horn etc.

Reconnaissance and Vision: Binoculars, Camera, Flashlight, Search Diagrams, Technical search equipment, pen, board etc.

Steps for Searching and Locating:

- Compile and analyse available information. Secure the scene
- Inspect and evaluate the worksite
- Rescue victims with easy access on or near the surface
- Select the area of search
- Select the proper tools for searching
- Conduct an appropriate search pattern
- Initiate pre-hospital treatment for the victims
- Confirm the presence and location of potential victims with resources, information and available equipment

8.19.1 Search Modalities

Hasty Search / Primary: is conducted to quickly detect the presence of survivors on the surface. Hasty search accomplishes the following: rapid detection of victims, set priorities

Extensive (Grid) Search / Secondary: This type of search is conducted in a methodical manner to pinpoint the exact location of victims. It is designed to cover the entire assigned area carefully and in detail. An extensive or grid search accomplishes the following: a thorough systematic search, redundant checks, and use of alternate search resources.
8.19.2 Search Methods

8.19.2.1 Physical Search - These operations do not require specialists or unique, expensive equipment. These only require senses and some established procedures. This search tactic is the first and sometimes, the only search method used by local rescuers who do not possess technical or canine search resources.

8.19.2.2 Canine Search - It uses the acute sense of smell among dogs, especially trained to detect live humans. Certified canine teams with highly specialized dogs (Fig.8.30) provide the best way to locate trapped victims in a large area in a very short time. They are able to access the areas too small or too unstable for humans to enter. Canines can be used for hasty and extensive operations. A thorough site search with two well-trained dogs has a high probability of conclusive results. The search dogs are trained to detect those victims that are alive. Rescuers should coordinate their activities with canine team during search operation.

8.19.2.3 Technical Search - requires highly trained personnel and specialized equipment for detection of sound, temperature, videos, vibrations etc. It can be carried out using specially manufactured or locally improvised equipment.

8.20 Basic rescue skills

8.20.1 Knot tying

Although there are other knots and hitches in rescue work, the ones mentioned below are the most common and should be learnt if you are to be a good rescue worker. Lives may depend on your being able to tie the right knot securely at the moment it is needed in light or dark, rain or shine. The use of natural fibre rope must be discouraged for the rescue of human life. For most other operations, natural fibre rope will suffice. Beware of ropes or straps that have been in the sun for some time; this may have weakened them. The important knots are simple figure eight knot, reef knot, clove hitch, figure eight-on-a-eight, sheet bend, bowline, round turn and two half hitches, timber hitch etc.

8.20.2 Emergency handling of casualties

The prime purpose of all rescue work is to arrange medical help as quickly as possible and get the injured people out of danger. When there are many casualties, the aim becomes one of trying to ensure the best use of time to effectively help as many people as possible. This decision-making process is called “triage.” In that, those responding to the incident are called upon to
examine all casualties quickly and rank them according to the level of need for both first aid and transportation to medical help. In any rescue or multiple casualty situation, confusion may be evident. It is essential that individuals assigned the job of helping injured people should remain calm and act quickly and carefully, always remain attentive to potential hazards to either themselves or other people in the area. In any situation where one suspects a possible head or spinal injury, if the life of the person is not under immediate threat, seek the help of specialists. If it is essential to move the casualty, and if one’s life is not in danger, maintain normal anatomical alignment (nose, belly button, inside of ankles). If the person is not in that position, get the help of qualified personnel.

Try to establish quickly how many casualties are there in the incident. Go to the nearest casualty, provided it is safe, and check for responsiveness. If the person does not answer or respond to attempts to wake him/her, check to see if the person is breathing. The aim is to keep the casualty alive until medical help arrives. One should not waste time dealing with minor injuries until all casualties have been found and stabilized.

If the person is not breathing, try to find someone nearby who is able to do artificial respiration until help gets in there. If the casualty is bleeding severely, apply a pressure bandage before moving to the next casualty. Remember, time is valuable. Give first aid for life-threatening conditions quickly and go to the next casualty.

### 8.20.3 One-rescuer methods

Never move the casualty any further than needed. Scan the escape routes to determine the best method and route to carry the casualty. If one is alone and must move the casualty quickly, try one of the following rescue carries: human crutch, drag carry, blanket drag, pick-a-back, removal downstairs, firefighter’s crawl etc.

### 8.20.4 Two-rescuer methods

If there are two people to do the carrying, try one of these emergency methods: chair lift, two-hand seat carry, or four-hand seat carry method.

### 8.20.5 Multi-rescuer methods

If there are more than two of you to do the job, there are a number of different methods that can be used to carry casualties. These include blanket lift, three-person lift and carry, improvised stretchers, blanket and poles stretcher,
stretcher, lashing casualty to stretcher, carrying stretchers etc.

**8.21 Five stages of rescue**

No hard and fast rules can be laid down for rescue work but, generally speaking, five stages of rescue are followed by trained rescue parties.

*Stage 1 - Reconnaissance and dealing with surface casualties*

Examine the site. Deal with surface casualties. Gather all possible information about other occupants of the building.

*Stage 2 - Location and removal of lightly-trapped casualties*

Immediate search - accessible areas for casualties, who can be rescued with minimal effort. Maintain contact with casualties inside who can be seen or heard but cannot be moved immediately.

**Note:** The use of trained air-scenting dogs can greatly increase the likelihood of finding trapped and conscious or unconscious casualties. Dogs used in this fashion should not be worn collars or harnesses that might trap itself when moving through debris. The paws should be checked regularly for injuries.

*Stage 3- Exploration of likely survival points*

Search the ruins and rescue all persons who can be seen or heard. This may include a calling and listening period.

*Stage 4 - Further exploration and selected debris removal*

Search farther into the ruins even where the chances of trapped people remaining alive seem remote. This includes removing debris from the likely places where casualties may be located.

*Stage 5- Systematic debris removal*

Strip selected areas of debris until all supposed casualties are accounted for. This includes removal of the dead bodies and detached body parts. Identify buildings that have already been searched by using spray paint or signs. This method can also be used to mark buildings that may contain bodies.

**8.22 Some Do’s and Don’ts**

Practise in the dark

To be a good rescue worker you should master all skills outlined in this booklet. One *should* be able to do them in the dark. Practise tying knots blindfolded and in cramped quarters.
Response to Landslide Disasters

What should be done before an emergency

- Volunteer to get involved with one’s municipality’s implementation of an Emergency Plan. One should call local authorities and let them know he is interested.
- Make a family emergency plan.
- Prepare a family emergency kit in case one needs to evacuate the premises.
- Get first aid training.
- Keep a list of emergency telephone numbers.
- Get all safety equipments (gloves, safety glasses, helmet, work boots, anti-dust mask) for protection ready.

What to do

- Think before the act and be careful.
- Warn or have somebody warn the authorities about the damages and the number of casualties in one’s sector.
- Do a reconnaissance before starting the work. This will not amount to wasting of invaluable time.
- Walk as closely to the wall as possible when on damaged stairs and upper floors.
- Use gloves when removing debris by hand.
- Be careful how you move debris from the vicinity of a casualty.
- Protect a casualty from falling debris and dust by using blankets, tarpaulins, corrugated iron sheets, etc.
- Keep off wreckage as much as possible; leave it undisturbed or destroy the neutral voids by further collapse.
- Be careful how you remove debris and obstacles, especially from voids, to prevent further collapse.
- Exercise great care when using sharp tools in debris.
- It is often necessary to use props or struts to strengthen a floor loaded with debris before passing over or working underneath it.
- In situations where the number of casualties is greater than the help available, do not waste time, use resources wisely.
- Examine a casualty before removal and give first aid only for life-threatening conditions.
• Free the nose and mouth of a casualty from dust and grit to ease breathing.
• Keep the casualty warm to slow the progress of shock.
• Make sure that the stretcher is properly blanketed so that the casualty has maximum warmth and comfort.
• Use appropriate procedures to carry a stretcher over debris and obstacles. Keep a list of all casualties handled.

Don’t
• Move an injured person without rendering first aid unless the casualty is in immediate danger.
• Smoke or light a match stick in case there is a gas leak.
• Crawl over debris or disturb parts of the damaged structure unless you are compelled by circumstances.
• Pull timber out of the wreckage indiscriminately to cause further collapse.
• Enter any site without informing the other members of your party or, if possible, without a companion to help in case of an accident.
• Touch loose electrical wiring.
• Throw debris aimlessly - one may have to move it again.

8.23 Safety in Rescue Operation

Rescue operations are the most complex and difficult activities that first responder teams faces. There may be numerous factors affecting safety during a rescue operation. Every rescuer should follow some basic safety rules like:

• **Personal Protective Equipment**: Anyone entering the area must be wearing personal protective equipment.
• **Hygiene**: To reduce as much as possible the contamination or contagion, one must wash his/her hands with soap and water before and after entering the work area; before and after eating and before and after using bathroom/toilets.
• **Safety Officer**: During the rescue work, one individual from the team will be designated safety officer. He/She will be in-charge of all safety related matters and will have the authority to partially or completely halt all activities.
• **Group Safety**: Each instructor and team leader will also be responsible for the safety of personnel in respective groups. Should one observe any unsafe action or condition, or an emergency, the safety officer should be alerted immediately. For this purpose, everyone will have whistle to use in an emergency.

• **Whistle Signals**: The safety officer will use the whistle to give alarm signals and alerts in the work area using the following signal system
  - One long signal - stop all work and listen for instructions
  - One long, one short - continue working
  - Three short signals - alarm signal, evacuate the area immediately to a previously designated safety zone

• **Safety Zone**: The safety officer will establish a safety zone near the work area. The safety zone will be used in case of any emergency requiring evacuation of the work area.

• **Emergency Medical Services**: A first aid kit and means of communications must be made available to ensure EMS arrival within 15 minutes, should the need rise.

• **Drinking Water**: During rescue work, the rescuers must carry a canteen or drinking water, to prevent dehydration.

• **Team safety**: All operations involving use of tools and equipment must be conducted in pairs, so that one person can use the tools/equipment while the other acts as a safety lookout. The person for safety lookout will use the signal system in which one tap on shoulder means to stop working, and two taps means to continue.
  - The Rescue Team Leader is responsible for the safety of his team members
  - When there is no designated safety officer in CSSR team, every team member must remain acutely aware of safety at all times and look out for each other
  - Every CSSR team members is responsible for giving warning about and preventing unsafe actions and/or conditions during all phases of CSSR operation

**SAFETY IS EVERYONE’S RESPONSIBILITY**

8.24 **Victim Management** - The following concepts and procedures should be applied starting from the moment the search is initiated and till the last victim is found.
Precautions during a search

- Never make inappropriate comments and keep a positive note. Always assume someone is listening to you (may be the victim?)
- The victim is in the worst possible position and fighting to stay alive, and you can enhance their chances of survival by being positive about the possibility of finding and extricating them
- You may be first person whom the victim is able to communicate with, therefore, it is important to project a sense of confidence and hope.

Steps for initial contact with a located victim

- Identify and overcome language barriers
- Identify yourself as a rescuer, projecting confidence and calm in your voice and choice of words
- Obtain the following information: Name, Adult or Child, Type and extent of injury, Hydration Status, Warmth, Degree of Confinement
- Provide emergency medical help as quickly as possible
- Ask about other potential victims and their condition
- Inform the victim of rescue operations
- Inform the victim if one has to leave for short periods
- Provide protection as much as possible from the environment
- Consider direct or indirect interventions of a relative or friend

8.25 First Aid

First Aid is the temporary help given to an injured or a sick person before professional medical treatment; it may also be termed as an emergency care offered to a victim of sudden illness or injury until more skillful help is available. This timely assistance, comprising of simple medical techniques, is most critical to the victims and may, often, save life and improve vitals. Any layperson can be trained to administer first aid, which can be carried out using minimal equipments. Basic training in first aid skills should be taught in school, in work places and, in general, be learnt by all, as it is mandatory to our modern and stressful life. Also, it is equally important to know what not to do in such situations.

There are several conditions that require first aid.
“First aid” is a catch-all phrase that refers to two distinctly different categories of medical needs.
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- Emergency first aid is the first positive response to an injury, illness or life-threatening (or limb-threatening) medical emergency. In this case more advanced medical care will follow. This type of first aid includes CPR, clearing an airway obstruction, responding to anaphylactic shock, splinting a broken bone, and severe bleeding control.

- Non-emergency first aid is the treatment for minor medical needs. We may or may not seek more advanced medical care after the initial response. This includes taking over-the-counter medications for minor pain or allergies, cleaning and bandaging cuts or abrasions, and minor bleeding control.

When you reach the victim, do the following:

- Assessment of the injured
- Is the person alive?
- Can s/he be removed from the site?
- Quick Triage
  (First attend to the one who is most likely to survive)

Lifting and Extracting injured people:

- Unless the accident site becomes unsafe or further damage likely, do not move the victim
- Do not retrieve if further damage is likely by one’s action
- Let injured arm hang free
- One should lock one’s arms under those of the injured to lift.
- Stabilize neck

Assessment of the Injured

- Check Pulse
- See Skin Color
- Assess level of consciousness (AVPU: A-Alert, V-Response to vocal stimuli, P-Response to painful stimuli, U-Unresponsive)

Seriously Injured Ones - ABCDE:

A - Airways
B - Breathing
C - Circulation
D - Disability (Neurological and others)
E - Exposure and Temperature Control
Halt further damage/injury; do no harm.

Airways - Look and Listen
- Look for vomitus / foreign bodies (in mouth and throat)
- Look for breathing efforts
- Listen any abnormal sound
- HEIMLICH’s maneuvers to clear foreign body from the wind pipe (trachea)
- Lift the chin
- Do not bend/tilt the neck unnecessarily

Breathing:
- Make sure that victim can breath
- Look for rib fracture
- Close open chest wound
- Mouth to mouth respiration

Circulation:
- Check pulse
- See colour
- Check for bleeding (may be internal ?)
- Control bleeding
  - No Tourniquet
  - Direct Pressure (Wound, Pressure point, Elevate the injured part)
- Control bleeding
- Check for fractured ribs
- For shock (Head down and legs up / raised)
- Do not remove the stuck sharp objects from the body before you can stop bleeding
- Tourniquets have done more harm than good

Stabilization
- Neck / spine stabilization (most important)
- Any trauma above the upper chest and neck should be considered as Cervical Spine Injury unless proved otherwise in the hospital
- May not have external / neurological signs of injury
- Place victims in most comfortable / neutral position
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- Utmost care to be taken during shifting / transfer
- Reassure the victim that help is at hand

Environment Control

- Halt further injury (damage)
- Prevent hypo / hyper-thermia
- Prevent suffocation / drowning
- Do not feed the victim?

Expert Resuscitation

- Suction
- Intubation
- Oxygen Therapy
- Medication
- Control of bleeding
- Cardio Pulmonary Resuscitation (CPR)
- Defibrillation
- Stabilization

Transportation

- Identify priority cases
- Get appropriate transport (vehicle)
- Appropriate personnel
- Closest versus Most appropriate centre
- Transport in “recovery position’
- Stabilize

(Caution - Transporting unconscious patients on his back without proper attention to his airways is a major cause of death due to ill-care)

First Aid for fractures

Spine Fracture:

- Move victims with great care. Will need many people
- Rolled towel can be used as a collar support
- Keep person’s spine as straight as possible
- Can strap him /her to a plank

Pelvic Bones fracture:

- Triangular Bandage
- Put pad between thighs
Fractured Arms:
- Sling and strap to his/her body

Legs fracture:
- Splint (with bamboo etc.)
- Splint to other leg

Survival Skills
- Avoid / Prevent
- Escape
- Communicate
- Do not be a victim while trying to be rescuer

If injured and if one is fairly conscious:
- Try to make oneself comfortable
- Be calm, do not panic
- Breath normally
- Move as little as possible
- Keep control on heart rate, BP, oxygen demand, blood loss, conserve energy, remain conscious longer

If injured, compress over the bleeding site. Cooperate with rescue team. Ensure your safety first and then help others, if you can.

Things to learn
- Patient in “Recovery Position”
- Vessel Compression\HEIMLICH Manoeuver
- Mouth to mouth artificial respiration\CPR

8.26 Relief

8.26.1 Financial Mechanisms: The 13th Finance Commission (2010 - 2015) constituted by the President on 13 November 2007, to give recommendations on specified aspects of Centre State Fiscal relations, has submitted its report to the President on 30 December 2009. Para 8 of the Terms of Reference (ToR) pertains to review of the present arrangements as regards financing disaster management with reference to the National Calamity Contingency Fund and the Calamity Relief Fund and the funds envisaged in the DM Act 2005.

The commission reviewed the existing arrangement of financing relief expenditure in light of the DM Act 2005 and recommended merger of the
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National Calamity Contingency Fund (NCCF) into National Disaster Response Fund (NDRF) as well as the merger of Calamity Relief Fund (CRF) into State Disaster Response Fund (SDRF) with effect from 1 April 2010 and transfer of balance in existing funds into new funds (please refer MHA notification and MoF Guidelines on NDRF and SDRF for more information).

The commission has assessed the relief expenditure requirements of all states and recommended that 75% of the SDRF requirement for general category States and 90% for the special category States be met by the Centre through a grant to the states.

FC-XII found considerable justification in widening the list of calamities covered under the scheme (FC-XII added landslides, avalanches, cloudburst and pest attacks in the existing list of six disasters - cyclone, drought, earthquake, fire, flood and hailstorm). FC-XII recommended that other disasters including chemical and industrial, as also air/railway accidents, may continue to be taken care by the respective ministries.

The claim on the NCCF is made through a memorandum submitted by the State Government, which is assessed by a central team deputed for the purpose. The report of the team is assessed by an inter-ministerial group (IMG), which makes recommendations to the high level committee (HLC) for release. The assistance from NCCF is only for immediate relief and rehabilitation and not for any reconstruction of assets or restoration of damaged infrastructure. In order to finance post-disaster reconstruction which is not covered under NCCF, Additional Central Assistance (ACA) has been given to States in recent years, particularly for Gujrat earthquake 2001, Tsunami 2004, Kashmir earthquake 2005 and Kosi flood 2008. In the year 2008-09, Rs.645 Crore was released to 10 States under ACA for long term reconstruction of assets.

The High Level Committee (HLC) will be constituted with Finance Minister, Agriculture Minister, Home Minister and Deputy Chairman of Planning Commission as members. HLC is serviced by the DM Division of MHA. Upon the approval of HLC, Ministry of Finance will release assistance from NDRF to the states.

Although the DM Act uses terms like ‘substantial loss of life, or human suffering, damage to and destruction of property and nature or magnitude as to be beyond the coping capacity of the community of affected area; it however does not quantify these terms.

As per DMA, NDMA shall recommend minimum standards for relief in terms of facilities in relief camps, relief to widows and orphans, ex gratia assistance
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Sub-Module 8

NDMA recommends the minimum standards of relief in terms of facilities to be made available in the relief camps, relief to widows and orphans, ex gratia assistance on account of loss of life and damages to houses and restoration of means of livelihood. The executive powers with regard to calamity relief as well as powers to ensure compliance with directions in carrying out the relief measures are vested with SEC.

Sections 46 and 47 of DM Act 2005 deal with the constitution of National Disaster Response Fund (NDRF) and National Disaster Mitigation Fund (NDMF). NDMF is to fund projects exclusively for the purpose of mitigation. NDRF shall be administered by the NEC to meet the expenses for emergency response, relief, and rehabilitation in accordance with the guidelines laid down by the Central Government in consultation with NDMA. Fund for Pooled Procurement - of relief material on short notice - often comes with an associated premium pricing and may adversely impact quality. An initial grant of Rs.250 Crores, in the form of revolving fund, has been provided to National Disaster Response Force for the purpose. NDMF is to fund projects exclusively for the purpose of mitigation and is to be administered by NDMA. Similar provisions have been made for the State and District Disaster Response and Mitigation Funds. Disaster Mitigation should be a part of plan process and the expenditure therein be met out of the plan resources of the respective ministries of the Union and the States. Second Administrative Reforms Commission recommended that disaster mitigation plans should be included in the development plans. The 11th Five year Plan Document emphasized on mainstreaming disaster management into development planning. Every development should include elements of impact assessment, risk reduction and ‘do no harm’ approach. The State Governments need to give priority to hazard identification and risk assessment in their plans and schemes.

The best methodology to assess the requirements of SDRF would be to base it upon Hazard-Vulnerability-Risk Profile of the States, as it would be a good indicator of disasters a state may face. However, there are no reliable exercise that maps the states on such a scale. In its absence, expenditure based approach would continue to be adopted. The existing list of natural disasters covers most of the prevalent events. However, for very specific events that could even be man-made and require high level of funding, but may have low chance of occurrence, financing of relief arrangements is left out to SDRFs.

The Public Liability Insurance Act (PLI), 1991, notified presently for specified quantities of 179 explosives, toxic and highly reactive chemicals, establishes
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the principle of liability for enterprises engaged in hazardous activities. Setting up of Environmental Relief Fund (ERF) under the Act in 2008 has further strengthened its provisions. As on 31st March 2009, the ERF has a corpus of Rs.285 Crore. The legal framework therefore, provides another source of relief for financing man-made disasters.

Effective disaster response requires trained manpower to deal with complex situations wherein effective and speedy handling can reduce the impact of a disaster on human life and property. It is necessary to continuously undertake measures to build capacity amongst those handling response and creating awareness amongst people. An additional grant of Rs.525 Crore has been recommended on the basis of the overall size of the SDRF of a state,. This amount may be used for taking up activities for building capacity in the administrative machinery for better handling of disaster response and for preparation of district and state level disaster management plans as envisaged in the DM Act.
9.1 Landslide Education

Landslide education will address the multifaceted aspects of landslide management, especially preparedness, mitigation and response efforts. In this regard, case histories of actual past disastrous landslides can be used as valuable inputs for disaster education in general, and landslides in particular.

The development of high-quality education materials, textbooks, field training and high standard of teaching at all levels should be given due emphasis. Education and training programmes should be designed, with greater focus on development of the capacity and skills of trainers and teachers. Science and technology courses designed by the experts and designated institutions should be introduced to orient all target groups including school teachers, NGOs and private volunteers and other professionals engaged in disaster management.

9.1.1 Education of Professionals

The knowledge institutions and universities should focus attention on landslide education through revision of syllabi, enlarging the scope of teaching earth sciences, civil engineering and allied disciplines with practical bias and through crafting of new educational programmes. The curriculum in earth sciences, engineering geology, seismology, geotechnical engineering, structural engineering and architectural aspects needs special attention. Another possible intervention is training of professional engineers and architects to ensure that classroom teaching benefits professional practice. A large number of professionals require training and retraining; endeavour should be to enhance on priority the quality of teaching, of text books, of training kits, etc. in the field of landslide education.

The country need to create a breed of professionals who can appreciate the importance of correct diagnosis before slope treatment. Geomorphologists have to perceive both macro and micro geomorphology and use it in slope analyses to deliver a message that present practices of dismembering slope into factors, such as relative relief and slope erosion. Engineering geologists should discuss micro-geological details controlling a landslide, and not just stop at broad description
Landslides Education, Training and Capacity Development

of lithology. A geotechnical engineer needs the education to realize that the orthodox soil mechanics has long been replaced by modern soil mechanics arming him with concepts, tools and techniques that can help characterize and analyse a landslide reliably. The landslide managers need the education they should insist on a scientific, systematic slope investigation and that ad-hoc measures without sound investigation may prove to be a costly waste.

There is a need to educate professionals in damage and loss assessment due to landslides and create simple tools and uniform procedures by which objective assessment becomes possible.

Technical institutes, polytechnics and universities located in vulnerable areas should develop adequate technical expertise on various subjects related to landslide management. The state governments, if required, in association with the University Grants Commission (UGC), Department of Science and Technology (DST), Ministry of Human Resources Development (MHRD), All India Council for Technical Education (AICTE) etc. will introduce short term Quality Improvement Programmes (QIP) for teachers and professionals engaged in teaching subjects related to landslides. The new technical programmes on the lines similar to those launched by various Central Ministries for college teachers, geoscientists, civil engineers, town planners etc. for developing the additional capacities in landslide management should also be taken up. The GoI should address the gap between the requirement and availability of quality teachers conversant with natural hazards, especially with the landslide assessment and mitigation techniques.

The subject of disaster medicine covers trauma care, epidemic control, emergency medical care by paramedics and emergency medical technicians, telemedicine etc. DM related medical education will receive due attention in undergraduate level, so that graduating doctors are able to handle emergencies with greater confidence. All architecture and civil engineering graduates should be taught in detail all aspects of landslides and related hazards in hilly areas of the country. These educational efforts should encapsulate improving the knowledge and skills of human resources by reviewing and updating the curricula periodically, upgrading the facilities, and institutionalizing the desired capacity building mechanisms in mitigating this hazard. The mainstreaming of landslide management in development planning will be supplemented with the development of the requisite infrastructure in technical and professional institutions, improved laboratories and libraries in identified R&D institutions. These measures should enable these institutions to undertake research and execute pilot projects on different aspects of landslides employing latest technology and set pace setter examples that will build confidence amongst geo-
scientists, geo-technical engineers and communities regarding management of landslides. The results of such studies should also help to develop and update the technical documents that may form important part of resource materials prepared for training programme on education, sensitisation and training.

9.1.2 Community Education and Awareness

The need for community education cannot be over-emphasized since it is usually the first responder to a disaster and their role in containing damage could be of prime significance. It is necessary that the government and the communities together evolve joint action plan aiming at spreading community awareness and development of community leadership. Such awareness will enable communities in ensuring safer constructions. Investments in Disaster Education, Public Awareness, Community Leadership Development, Disaster Education of unemployed youth, physically challenged, elderly, women and school children should be encouraged.

9.2 Training

The geologists from Geological Survey of India (GSI) and State Directorate of Geology and Mining (DGMs) in landslide affected states should be involved in landslide hazard mitigation programmes and studies after proper training. A large number of engineers are involved in the construction activities at the civil engineering and infrastructural project sites in landslide affected areas. Such training programmes should be offered to these professionals as well. The training modules may include both in-class and on-field training.

Fig. 10.1: People engrossed in Village Level Community Based Training on Disaster Management
9.2.1 Training of Professionals

Geologists, engineers and other professionals related to the field of landslide will be exposed to latest developments in the domain of landslide investigations and management being evolved globally on regular basis so that well trained manpower conversant with latest technological advances is available in the country to manage the hazard effectively. This can be done by sending these professionals abroad regularly to acquire theoretical knowledge as well as practical experience on application of latest and more effective techniques. The training programmes will be systematically planned and executed with extensive interdisciplinary exposures for engendering a trained manpower tuned to holistic management of landslides.

These training programmes should be pilot tested, critically evaluated, upgraded, documented, and peer reviewed at regular intervals. The training modules will be continuously updated based on the evaluation and feedback from participants.

In the initial phases, training may be imparted to all engineers, geologists, geophysicists, hydrologists from DGMs and other departments involved in developmental activities in hilly regions, especially in the ULBs and PRIs of such States. In particular, the design directorates, if any, in the State Departments will ensure that they have architects and engineers with background in landslide-safe design and construction. Those who undergo the ‘Training of Trainers’ programmes will have the onus of training the professionals through a network of professional societies. Minimum acceptable standards of safety, as enumerated in BIS codes, will be disseminated through professional organisations and the training requirements will be integrated with the licensing criteria.

9.2.2 Recommended Areas Requiring Training

- Geomorphological, geotechnical, hydro-geological and GIS based LHM with perception of mapping scales
- Geotechnical Investigation of landsides with particular reference to characterization of slopes, elucidation of landslide boundaries, representative undisturbed sampling from shear zones, handling of samples, simulated stress-path testing and stability analyses in terms of total and effective stresses
- Techniques of monitoring slope surface and sub slope movements and movement rates and cross linkage with rainfall record, piezometric profiles and behaviour of buildings and structures on slopes
Sub-Module 9

Training Programme on COMPREHENSIVE LANDSLIDES RISK MANAGEMENT

- Slope modeling
- GIS based landslide hazard, vulnerability and risk assessments
- Slope kinetics, site effects and earthquake induced landslides in seismic micro-zonation and risk assessment
- Instrumentation of slopes, landslides and avalanches, and early warning
- Design of landslides and avalanche control measures with particular reference to choice of technologies
- Training of first responders in search, rescue and medicare
- Training of communities and local bodies

Training for visual, print and electronic media in the science of disasters for improved and more objective reporting

9.3 Capacity Development

Mechanism should be developed to identify institutions active in the field of landslides, assess capabilities, enhance and strengthen capacities in terms of expertise, knowledge and resources for effective management of landslide hazard. Main areas requiring capacity development in landslide disaster management are as follows:

- Establishment of a nation-wide organized vibrant pro-active, systematic and scientific institutional mechanism that would replace the current piecemeal, ad-hoc, less recognized and poorly appreciated landslide management practices
- Enhancement of expertise and capacities of knowledge centres in different parts of the country for dependable and timely geomorphological, geotechnical and hydro-geological investigations and for scientific design and speedy and effective implementation of control measures.

Strengthening a few objectively identified institutions, their units and departments in all states and union territories to redefine and enlarge their respective mandates/roles to provide/support pre and post landslide routine/specialized functions.

9.4 Awareness

As a part of awareness generation exercise of landslide hazard mitigation effort, GSI, in consultation with the MHA, initiated a programme to establish contact with various state governments in landslide affected states and create awareness about this natural hazard among the state officers and other agencies
Training Programme on COMPREHENSIVE LANDSLIDES RISK MANAGEMENT dealing with natural hazards. The programme include audio-visual presentation and distribution of booklet and posters for generating awareness about landslide hazards, familiarising landslide terminologies, causes, treatment measures etc. GSI Training Institute also conducts training programme on regular basis on various aspects of landslide investigations.

NIDM has the mandate to develop training modules, undertake research and documentation in disaster management; provide assistance in national and state level policy formulation; develop educational materials for disaster management and promote awareness for hazard mitigation, preparedness and response measures. Indian Institute of Remote Sensing (IIRS), Dehradun also conducts both short and long term courses especially for orienting the people in the usage of remote sensing data for geological hazards. The Decision support centre at NRSA conducts a two week course for various planners at State and District level in the usage of EO data for hazards.

The mass awareness generation programme is to be made essential component of disaster mitigation plan and is planned to be carried out as sustained effort through electronic and print media, interactive meets and distribution of handbills and posters in local languages. Different NGOs, State Government Authorities have also to undertake exhaustive programmes for mass awareness generation. A series of audio-visual resource material on this aspect has to be prepared and distributed to the above mentioned organizations for this purpose. The services of media, private volunteers and NGO’s active in the field of disaster related work can be effectively utilized for this purpose after proper orientation.

Large number of engineers and geologists engaged in landslide hazard management do not possess requisite expertise to manage this hazard. Landslide hazard management techniques, risk assessment and remediation practices are required to be included in the curriculum of technical institutes teaching civil engineering, geology, geophysics and disaster management.

Local communities aware about landslide hazards and their locales, would be in a better position, both physically and psychologically to face consequences. Since landslides are frequent and sudden and cause disasters that affect localized areas resulting in segregated losses, these do not receive appropriate attention due to transitory nature and short-lived human memory. Hence, the level of awareness about landslides has been quite low compared to other disasters like earthquakes, floods and cyclones. In our country’s hilly terrain, cumulative losses due to landslides are much higher than any other disaster. Thus, there is an immediate need to educate people about landslides so as to reduce the associated risk / losses.
State Governments / State Disaster Management Authorities (SDMAs) of landslide affected state areas will, in collaboration with the GSI and other key stakeholders, make special efforts to mobilize communities to carry out landslide mitigation efforts. Electronic and print media will also be associated in the endeavor to create greater public awareness about landslide hazard and the importance of landuse zoning practices. Comprehensive awareness campaigns targeting different groups of people living in landslide prone areas, will be carried out systematically. These campaigns will emphasise on the prevalent landslide risk and vulnerability of the areas as well as highlight the roles and responsibilities of communities and stakeholders in addressing this risk. These will also focus on the specific role that each institution/ organization or community will play in order to mitigate the effects of landslides.

9.5 Creation of Public Awareness on Landslide Risk Reduction

Handbooks, posters and handbills containing status of landslide hazard should be distributed and details of landslide indicators along with precautions to be adopted and suggestive measures should be displayed near the landslide prone sites. All above documents should be translated into local and regional languages. Short video films on the landslide risk, vulnerability and importance of preparedness and mitigation measures should be prepared for the benefit of local public. The electronic and print media should also be made integral part of such campaigns.

Communities need to be alerted and made aware of:

- the major disaster threat perceptions in the localities of immediate concern, and the projected disaster scenarios (landslide included)
- the possible landslide hazard distribution scenarios and major known landslide spots and identified elements at risk
- the lessons learnt from the past landslide disasters in the areas and also their (mis)management, if any
- the precursors and early indicators that can avert landslide disaster
- the roads, housing, schools etc. exposed to landslide risk
- the role and responsibility of the government and local bodies before, during and after a disaster
- the expected roles and responsibilities of communities and people at large before, during and after a disaster; the responsibility the residents and communities are willing to shoulder in choosing to live or to do business in high risk areas
9.5.1 Awareness Drives for Specific Target Groups

One of the most challenging tasks in landslides preparedness and mitigation is the sensitization of stakeholders, and educating and training them to participate in landslide preparedness and mitigation efforts. If the community recognizes the importance of landslides safety vis-à-vis developmental activities, tremendous gains can be achieved in landslide risk reduction.

Big construction companies and contractors engaged in infrastructure development in the hilly regions will undertake campaigns to sensitize their members on the risk and vulnerability resulting from landslides in various parts of the country so that necessary attention to prevent this hazard and mitigation measures are included in designs and construction in vulnerable areas.

A comprehensive awareness campaign should be developed and implemented for following safe practices before, during and after a landslide. The campaign should also highlight the risks and vulnerability of the states and the roles/responsibilities of all communities and stakeholders in addressing the risk.

Public awareness campaigns should be conducted at the national, state and district centres and in high risk areas for disseminating information on landslide risk management among all stakeholders. Case studies documenting the major landslides should be prepared and used for creating greater public awareness among professional and critical stakeholders. Landslide risk management should be done by applying available knowledge and customizing the same through R&D for specific situations and generating new adaptive techniques.

9.6 Landslide Preparedness

DM plans for landslide prone areas should be systematically developed such that stakeholders are able to address landslide risk. These plans should be region specific and should consider the risk profile and the special characteristics of a particular geographic area. Preparedness should include the formulation of family and community contingency plans. Mock drills should be conducted in offices, schools and industrial units etc. and in the neighbourhood of the sites vulnerable to landslides.

The people operating in the mountainous regions will be sensitized about the landslide hazard. They would be advised to remain vigilant and respond effectively in emergency situations.
An exercise in real sense is a focused practice that puts the participants in a simulated situation to function in the capacity that would be expected of them in a real event. Its purpose is to promote preparedness by testing policies and plans and training personnel.

Exercises should be conducted to evaluate an organization’s capability to execute one or more portions of its response or contingency plans. Many successful responses to emergencies over the years have demonstrated that exercising pays huge dividends.

Comprehensive exercise programme involves five main types of activities, viz. orientation seminar, drill, tabletop exercises, functional exercises and full-scale exercises.

As per the specific situation these exercises will be conducted to assess the preparedness for all possible hazards present in an area taken together.

**9.6.1 Medical Preparedness**

The disaster management plans related to medical preparedness developed at the state and district levels will be same as in other hazards. The principal aim of the medical management plan will be to improve emergency medical preparedness and emergency medical response. In case of landslide hazard, the medical preparedness should focus on likely injuries resulting from landslides including psycho-social trauma. It should address the need for surveillance and for planning and rehearsing for disaster preparedness through mock exercises.

Since Medical Management Plans include all disasters existing in the area, there is a need to create greater awareness in all medical teams and the medical community at large about all hazards and types of injuries that can be inflicted especially by landslides.

All public health facilities will develop their own DM plans, with the scope for enhancing their surge capacity in the event of disaster. Training exercises and mock drills will be carried out regularly by doctors and paramedical staff. The medical preparedness plans will also include identification of trained trauma and psycho-social care teams, with nursing and paramedical staff. In high-risk landslide areas, mobile hospitals and Quick Reaction Medical Teams (QRMTs) should be developed as part of the overall disaster health-care delivery system of the states to manage patients with minor injuries at the incident site itself.

The state governments will identify the hospitals, team of doctors and paramedics including mental health and psycho-social service provider at sub-
divisional and district levels, who will be deployed at short notice. Their names, addresses, telephone numbers, mobile numbers, email etc. will be made available to the district and state control rooms. The list will be updated annually. The stock of medicines, accessories and equipment for each of identified teams at the district and sub-divisions will be assessed and updated in advance as per needs.

9.6.2 Animal Care

Animals both domestic as well as wild are exposed to the effects of natural and man-made disasters. It is necessary to devise appropriate measures to protect animals and find means to shelter and feed them during disasters and their aftermath, through a community effort, to the extent possible. It is pertinent to note that many communities have shown compassion to animals during disasters, and these efforts need to be formalized in the preparedness plans of the Departments of Animal Husbandry at the Centre and the States.

9.7 Preparedness Plan for Landslides

Landslides are a serious geologic hazard that causes thousands of deaths and injuries each year throughout the world. Often associated with periods of heavy rainfall or rapid snow melt, landslides are capable of rapid movement with enormous destructive capacity. Earthquakes can also trigger landslides. Landslide preparedness involves individuals knowing about the hazard potential where they live and taking various steps to reduce the personal risk from this geologic phenomenon. Landslide usually strike without warning. The force of rocks, soil, or other debris moving down a slope can devastate anything in its path. The following steps should be taken to keep one in readiness.

9.7.1 Pre-disaster Preparedness

If one is at risk from landslides, one should:

- Develop an evacuation plan. If the home could be damaged in a landslide, one should know where to go. Making plans at the last minute can be upsetting, create confusion, and waste precious time. Contact local authorities to learn about the emergency response and evacuation plans for the area and develop own emergency plans for family and business.

- Familiarize oneself with the land around one. It will help in assessment of risk.
• Watch the patterns of storm water drainage on slopes near homes, especially the places where runoff water converges, increasing flow over soil covered slopes. Watch the hillsides around homes for any signs of land movement, such as small landslides or debris flows, or progressively tilting trees.

**Noticing small changes could alert you to an increased threat of a landslide.**

• Discuss landslides and debris flows with members of household. Everyone should know what to do to stay safe if one occurs.

• Be aware that, landslide insurance is generally, not available; however, in some cases, debris flow damage may be covered by flood insurance policies.

• Get a Ground Assessment of the property.

• Seek specific information on areas vulnerable to land sliding from a geologist. Consult a professional engineering geologist or a geotechnical expert for opinions and advice on landslide problems and on corrective measures one can take.

• Minimize home hazards. One can reduce the potential impacts of land movement by taking steps to remove oneself from harm’s way.

• Plant ground cover on slopes and build retaining walls. In mudflow areas, build channels or deflection wall to direct the flow around buildings. (Remember: If one build walls to divert debris flow and the flow lands on a neighbor’s property, one may be liable for damages).

• Build away from steep slopes.

• Build away from the bottoms or mouths of steep ravines and drainage facilities.

**Learn to recognize the landslide warning signs**

• Doors or windows stick or jam for the first time.

• New cracks appear in plaster, tiles, bricks, or foundations

• Outside walls, walks, or stairs begin pulling away from the building

• Slowly developing, widening cracks appear on the ground or on paved areas such as streets or driveways.

• Underground utility lines break.
Landslides

Education, Training and Capacity Development

- Bulging ground / wall appears at the base of a slope.
- New holes or bare spots on hillsides
- Water breaks through the ground surface at new locations.
- New springs appear or sudden disappearance of existing springs
- Muddy water in creeks, rivers
- Fences, retaining walls, utility poles, or trees tilt or move.
- One hears a faint rumbling sound that increases in volume as the landslide nears. The ground slopes downward in one specific direction and may begin shifting in that direction under the feet.

Make evacuation plans

- Plan at least two evacuation routes since roads may become blocked or closed.
- Develop an emergency communication plan
- In case family members are separated from one another during a landslide or mudflow (this is a real possibility during the day when adults are at work and children at school); have a plan for getting back together
- **Develop a family plan that includes** out-of-locality family contact number, place to join up if family members are separated, decide the safe routes to leave for secure place, and locations of utility shut-offs. After a disaster, it’s often easier to call long distance. Make sure everyone knows the name, address, and phone number of the contact person
- **Keep ready emergency supplies like** Food, Water, First aid kit, Flashlights and batteries, Battery-operated radios, Special medications/eye care products
- **Prepare an evacuation kit that includes** Cash (small bills and change), Important documents (Birth certificates, insurance policies, marriage certificates, mortgage documents), Games, toys for children
- **Purchase supplies to protect your home. It may include** Hammer, Nails, Plywood, Rain gauge, Sand, Sandbags, Shovel
- Listen to the radio or watch television for information and instructions from local officials
- Respect the power of the potential landslide. Remember, landslides move quickly, can cause damage and kill people
Insurance

- The local insurance companies can cover mudflow and landslide risks under natural calamities.

Landslide Preparedness and Prevention for Oceanside Residents

- With last winter’s heavy rains, the ocean-side and the coastal parts may suffer devastating landslides.
- If there is another potentially wet winter, the Coastal States should initiate an educational program regarding Landslide Preparedness and Prevention for Oceanside residents.
- While entire landslide damage cannot be prevented, this web site offers practical advice on how home and business owners can take a number of precautions to make their property safer.
- As it is the property owner’s responsibility to protect the stability of one’s property, one should take this opportunity to learn how to protect property and recognize potential landslide risks.
- Eliminate litter and dead and dry plants.
- Inspect slopes for increases in cracks, holes and other changes.
- Contact local public works department for information on protection measures.

What to do during a landslide

- Quickly move out of the path of the landslide or debris flow - Moving away from the path of flow to a stable area will reduce risk.
- If escape is not possible, curl into a tight ball and protect your head. A tight ball will provide the best protection for body.
- Take cover under a sturdy table or desk if inside the house when landslide is moving.
- If outside, try to get out of the path of landslide or debris flow; Run to the nearest high ground in a direction away from the path of landslide.
- If rocks or debris are approaching you, run the nearest shelter such as group of trees or big and heavy rock mass that are unlikely to move with slide.
- A sinkhole occurs when ground water dissolves a vulnerable land surface such as limestone, causing land surface to collapse due to lack of support.
What to do after a landslide

- Stay away from the slide area - There may be danger of additional slides
- Go to established meeting point and follow instructions by the assigned responsible person
- Check for injured and trapped persons near the slide, without entering the slide area directly. Direct rescuers to their locations.
- Help a neighbor who may require special assistance, e.g. infants, elderly people and people with disabilities. People who care for them or who have large families may need additional assistance in emergency situations.
- Give first aid to victim, if you are trained
- Listen to local radio or television for the latest emergency information
- Watch for flooding, which may occur after a landslide or debris flow. Floods sometimes follow landslides and debris flows because they may both be started by the same event
- Look for and report broken utility lines to appropriate authorities. Reporting potential hazards will get the utilities turned off as quickly as possible, preventing further hazard and injury
- Check the building foundation, chimney and surrounding land for damage. Damage to foundations, chimneys or surrounding land may help one assess the safety of the area
- Replant damaged ground as soon as possible since erosion caused by loss of ground cover can lead to flash flooding
- Seek the advice of landslide expert for evaluating hazards or designing corrective techniques to reduce landslide risks. A professional would be able to advise you ways to prevent or reduce landslide risk, without creating further hazard.

9.8 Survival Skills

Live by Your Wits, But for Now, Learn Basic Skills

Without training in basic skills for surviving and evading on the battlefield or on after disaster, your chances of living in evasion situation are slight.

Learn these basic skills now—not when you are headed for or are in survival situation. How you decide to equip yourself before deployment will impact on
whether or not you survive. You need to know about the environment to which you are going, and you must practice basic skills geared to that environment. For instance, if you are going to a desert, you need to know how to get water in the desert.

Practice basic survival skills during all training programs and exercises. Survival training reduces fear of the unknown and enhances self-confidence. It teaches you to live by your wits.

**Train Yourself to Survive**

There is need to train you to survive. But don’t make the mistake of thinking that being in a survival situation would be fun. Wilderness Survival is not a game, there are no reward challenges, and there is no immunity. How do you think you would fare in a survival situation? Could you build a shelter? Could you forage for food and purify water? In real life you don’t have luxury items, you don’t get tarps and matches and camping supplies. In real life you may not have any tools except your own two hands. If you were stranded in the wilderness would you end up a survivor?

Don’t worry about those questions. Instead take action and educate yourself on survival techniques. Nature is unforgiving and you must be prepared to fight to stay alive.

Expand the meaning of each letter of the word survival. Study and remember what each letter signifies because you may some day need SURVIVAL.

S - Size up the Situation
(Surroundings, physical condition, equipment)
U - Use All Your Senses, Undue Haste Makes Waste
R - Remember Where You Are
V - Vanquish Fear and Panic
I - Improvise
V - Value Living
A - Act Like The Natives
L - Live by Your Wits, But for Now, Learn Basic Skills
10.1 Initiatives on Development and Disaster Risk Reduction

The Central Government, State Governments, Public Sector Units and Private Entrepreneurs in the country are engaged in some kind of developmental activities which can enhance or reduce the disaster risks. Thus, development may have both positive or negative impacts on disaster risks. Similarly disasters also provide an opportunity to learn from our mistakes and help us identify good as well as bad practices. The destruction during disasters demolishes the non-resilient structures whereas the resilient ones may remain safe and functional. Post disaster reconstruction and redevelopment should, therefore, promote application of disaster resilient features more for safer sustainable development. Mainstreaming DRR is one such initiative taken by Government of India to develop a culture of prevention and mitigation into the development process. Major developmental programmes of the Government of India which may have wider impacts on DRR are discussed briefly. National Rural Employment Guarantee Scheme (NREGS) under NREG Act assure financial relief to the needy families in drought affected areas. NREGA serves the larger objective of enhancing agricultural productivity because the first priority under NREGA is given to projects aimed at water conservation. Such schemes can be easily integrated with relief programmes to increase the availability of funds for relief expenditure. Similarly Indira Awa Yozana (IAY) accomplished useful relief works in terms of providing housing to the affected families. 10% of the annual allocation under IAY is earmarked for this purpose. Likewise allocation (5%) is also made under the Accelerated Rural Water Supply Programme (ARWSP). National Rural Health Mission provides broad based improvement in health care for rural population. Rashtriya Swasthya Bima Yojana is a new and important innovation providing the population below poverty line with an insurance policy covering hospital treatment for a defined set of conditions with government meeting the premium wit. Bharat Nirman Programme focuses on the provision of key elements of rural infrastructure such as irrigation, rural electrification, rural roads, rural drinking water supply, sanitation, housing for the poor, and rural connectivity via community IT services. Rashtriya Krishi Vikas Yojana (RKVY) incentivize State governments to prepare district
level agricultural plans that take account of local conditions. Swarna Jayanti Shahri Rozgar Yojana (SJSRY) to provide gainful employment to the urban unemployed (below poverty line) as well as Urban Poverty Alleviation and Slum Development to improve. Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT) seeks to provide central assistance for urban infrastructure development linked to a process of reforms at the city and urban local body level which would make these bodies more financially viable, and ultimately capable of financing the investment needed in urban areas.

National Highways Development Programme (NHDP) includes four laning of the Golden Quadrilateral and the North-South, East-West Corridors; 4/6 laning of 10000 km of national highways connecting State capitals and places of tourist importance with the national network (implemented by NHAI). Special Accelerated Road Development Programme for the North East Region (SARDP-NE) is presently under implementation for providing road connectivity to all State capitals and district headquarters in the NER. The 11th plan outlined a broad approach based on Integrated Energy Policy formulated earlier by the Planning Commission. National Food Security Mission launched in 11th Plan aims at increasing production of cereals and pulses. Pradhan Mantri Gram Sadak Yojana (PMGSY) extends rural connectivity. PMGSY aims to provide reliable road connectivity to all habitations with 1000+ population (500+ Population in Hilly regions). Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) has ambitious plans to extend rural electrification to hitherto unserved rural areas. RGGVY aims not only at household electrification but also at energization of pumpsets. Accelerated Power Development and Reform Programme (APDRP) aims at reducing aggregate technical and commercial losses. Mid-Day Meal Scheme and the Sarva Shiksha Abhiyan (SSA) brought additional children to schools. Accelerated Irrigation Benefit Programme (AIBP) incentivize States to complete projects in a time bound manner. Command Area Development Programme (CADP) was modified in 10th Plan to include water management. A model Participatory Irrigation Management (PIM) Act has been circulated to States to promote PIM to improve irrigation water distribution to all farmers, including the tail enders. Under the Environment (Protection) Act 1986, the Central government can intervene where the water table falls (otherwise as per Easement Act of 1882, the ownership rights of groundwater rest with the owner of the land). River Conservation Programme to ensure that river flows are adequate to provide water of at least bathing quality standards. A comprehensive action plan for Yamuna and Ganges (Ganga Action Plan) has been prepared. Similarly National Lake Conservation Plan (NLCP) for
conservation of 46 lakes in 13 States has been taken up through 31 projects (e.g. Dal Lake Conservation Project). A National Action Plan on Climate Change and Clean Development Mechanism (CDM) are being prepared.

It is estimated that the earth’s surface temperature has risen by 0.6±0.2°C over the 20th century. In the last 50 years, the rise has been 0.13±0.07°C per decade and the recent years have been warmest since 1860, the year from which regular instrumental records are available. Recognizing the importance of climate change issues, the Prime Minister established a Council on Climate Change under his own chairmanship in June 2007 to coordinate national action for assessment, adaptation and mitigation of climate change. An action plan for adaptation to climate change would require (i) action in the area of agricultural research to evolve varieties that can cope with likely climate changes, (ii) action to cope with likely increase in water stress, (iii) action to be able to cope with a greater frequency in natural disasters. In 1997, the Kyoto Protocol under United Nations Framework Convention on Climate Change (UNFCC) was adopted. Bali Action Plan came into being after the 13th Conference of Parties at Bali in December 2007 to enable the full, effective and sustained implementation of the Convention through long-term cooperative action. It is argued that with a share of just 4% of global emissions, any amount of mitigation by India will not affect climate change. National Environment Policy of 2006 requires ‘equal per capita entitlements of global environment resources to all countries’. India’s per capita emissions never exceed the per capita emissions of the industrialized countries. This formulation focuses on per capita emissions rather than total emissions as the relevant variable, and also provides industrial countries with an incentive to reduce their level of emissions as quickly as possible. With urbanization and concentration of population in metropolitan cities, more and more people are becoming vulnerable to locational disasters.

The 10th Five Year Plan (2002-07), prepared in the backdrop of Orissa Supercyclone, Gujrat earthquake, and the end of IDNDR, recognized disaster management as a development issue for the first time. The plan devoted a separate chapter to disaster management and made a number of important prescriptions to mainstream DRR into the process of development. The prescriptions of 10th Plan can be broadly divided into 3 categories: (i) Policy guidelines at macro level that would inform and guide preparation and implementation of development plan across sectors; (ii) Operational guidelines for integrating DM practices into development; (iii) Specific development schemes for prevention and mitigation of disasters.
Mainstreaming Landslides Risk Reduction in Development

The plan called for a 'multi-pronged strategy for total risk management, comprising prevention, preparedness, response and recovery, on one hand and for initiating development efforts aimed towards DRR and mitigation on the other hand' to achieve sustainable development. The plan suggested development of SOPs for dealing with humanitarian and relief assistance from non-government sources.

- Building disaster prevention and preparedness in development planning by introducing a rigorous process of vulnerability analysis and risk assessment, maintaining data base and resource inventories at all levels, developing infra-structure for mitigation and establishing Disaster Knowledge Network for use of disaster managers, decision makers, community and so on.

- Encouraging community level initiatives for disaster preparedness by involving people at grass root level, particularly those who are vulnerable.

- Developing appropriate zonal regulations, design standards, building codes, and performance specifications for safe construction.

- Inclusion of disaster mitigation analysis in all development schemes in vulnerable areas and building disaster mitigation components into all development projects.

The 10th Plan recommended creation of faculties in disaster management in all 28 states, in addition to community mobilization, human resource development, establishment of control rooms and forging international cooperation in disaster management. A Central Sector Plan Scheme, the National Disaster Mitigation Programme (NDMP), has been implemented since 1993-94. The scheme mainly provided training and capacity building of government functionaries and other stakeholders to manage disasters effectively. This scheme was transferred from Ministry of Agriculture to Ministry of Home Affairs in June 2002. The allocation of this scheme was raised from Rs.6.30 Crore in 8th Plan to Rs.16.32 Crore in 9th Plan and to Rs.30.77 Crore in 10th Plan. Presently there are 29 DMCs in 28 States/UTs besides NIDM at national level, who undertake research, consultancy and documentation for disaster management. NIDM has been set up for training, capacity building, research and documentation on various natural and manmade disasters. A comprehensive human resource plan for DM has also been prepared. 29 DMCs run in the States/UTs and 6 Centres of Excellence are allocated Rs.30 lakh and Rs.25 Lakh per annum respectively. The total financial allocation is Rs.25 Crore over a period of 5 years from 2007 to 2012. The allocation of Rs.21.90 Crore to the training institutions during 10th Five Year
Plan was mainly used by NIDM which incurred an expenditure of Rs.11.56 Crore. Nearly 71,000 persons have been trained under the programme.

The National Building Code has been revised, taking into consideration the natural hazard and risks of various regions of the country. The National Programme for Capacity Building of Engineers in Earthquake Risk Management (NPCBEERMM) aims to train 10000 engineer and NPCBAERM aims to train 10,000 architects on safe construction techniques and practices. MHA implemented DRM programme (2002-2009) in 176 (earlier 169) multi-hazard districts and 38 cities in 17 states. The DRM programme ended in June 2009. It had a multi-donor resource framework of USD 41 million and was the largest CBDRM programme in the world. One of the sub-components of DRM programme was Urban Earthquake vulnerability Reduction Project (UEVRP) implemented in 38 cities with over half a million population in seismic zone III, IV and V across India. It was completed in December 2009. Under this programme, DM plans are being prepared from villages to districts; DM teams are being constituted and training is imparted on various aspects of DM at all levels. The new DRR programme with an outlay of Rs.100 Crore (USD 20 million) is being implemented in 80 districts of 26 States and URR component is being implemented in 58 multi-hazard prone cities of 23 States. The programme has 2 components (i) Institutional Strengthening and Capacity Building for DRR with outlay of Rs.63 Crore (USD 12.6 million) and (ii) Urban Risk Reduction with an outlay of Rs.37 Crore (USD 7.4 million). The Programme Management Board is headed by Secretary (BM), Ministry of Home Affairs.

GoI-USAID Disaster Management Support Project was signed in 2003 and extended upto 2015. The total outlay of the project is USD 4.715 million (comprising USD 420,000 for training studies, USD 500,000 for equipment and USD 3,795 million for technical assistance) and USD 5 million to integrate DRR and Climate Change.

An 10 battalion strong NDRF (2 bn each from BSF, CRPF, CISF and ITBP) has been set-up comprising 144 specialized response teams on various types of disasters of which 72 teams are for NBC disasters. Each battalion provides 18 self contained specialist search and rescue teams of 45 personnel each including engineers, technicians, electricians, dog squads, doctors and paramedics. The total strength of each battalion will be approximately 1,158. Four Training Centres will be set up in Kolkata, Latur, Bhanu and NISA (Hyderabad) by respective paramilitary forces to train personnel from NDRF battalions of respective forces. A national level Disaster Management Academy at Nagpur will be setup to provide Training of Trainers and to meet other national/international commitments. National
Disaster Mitigation Resource Centres (NDMRC), co-located with NDRF, serve as repositories of relief stores for 25,000 affected people in each location. These will cater to emergent requirements especially for the first 72 - 96 hours. At Kolkata and Chandigarh, additional bricks of stores for 50,000 people each will be kept for high altitude areas.

National Fire Service College (NFSC), Nagpur is mandated to train personnel in all spheres of fire engineering. A scheme for upgradation of NFSC was launched in June 2010 to meet the requirements of specialized professional training in all aspects of emergency management, especially fire. National Civil Defence College (NCDC), Nagpur is one of the main centres for disaster relief and management training and a nodal centre for CBRN emergency response. The college has been upgraded to an Institution of Excellence to train a professional cadre of trainers for disaster response and recovery management.

The Civil Defence (CD) set-up is being revamped to strengthen local efforts for disaster preparedness and effective response. GoI launched CSS in April 2009 with an outlay of Rs.100 Crore during 11th Plan for revamping CD setup in the country. Similarly Fire Services are also being strengthened / modernized to convert them to multi-hazard response force. A scheme for strengthening Fire and Emergency Services was launched in 2009 with an outlay of Rs.200 Crore in the 11th Plan. The office of the DG NDRF&CD is the implementing agency. It includes procurement of items, awareness generation/school safety programme, ToT on search, rescue and fire fighting, fire hazard and risk analysis, project management and monitoring. A grant of Rs.87,519 is allocated to Urban Local Bodies, a portion of which is available for revamping of fire services within their respective jurisdiction. All municipal corporations with a population >1 million (2001 census) must put in place fire hazard response and mitigation plan for their respective areas. An additional fund of Rs.472 Crore has been allocated to 7 States (Andhra Pradesh, Haryana, Mizoram, Orissa, Tripura, U.P. and West Bengal).

The 10th Plan has set into motion the process of shifting focus from response centric to prevention, mitigation and preparedness - as means to avert or soften the impact of future emergencies. The 11th Plan aimed at consolidating the process by giving impetus to projects / programmes that develop and nurture culture of safety and the integration of prevention and mitigation in development. Hazard identification and risk assessment must be bound by uniform procedures, fine tuned to local conditions. In the absence of such procedures, any sporadic activity based on some ad hoc procedures carries the potential of doing more harm than good. Conceptualization of
damage scenarios requires quality scientific studies in a multi-disciplinary environment, and generation of new data, besides filling data gaps. The data gaps and assumptions made, and their implications should be clearly brought out. Data sharing among various data generators needs to be addressed. All schemes getting Plan funds will be treated as national assets and data would be made available without any pre-condition for use for DM authorities and others. High resolution geospatial database to facilitate temporal analysis of future assessment impact studies in area and also enable integration of all other assessment studies, to evolve a national database. The reliability of hazard, vulnerability and risk assessment will depend upon the quality of maps and other investigation data and various uncertainties involved due to inadequacy of data and other factors. All major stages of development, namely planning, site investigations and designs, are subject to a process of rigorous peer review and accordingly certified.

Mainstreaming DM into development essentially means looking critically at each activity that is being planned, not only from the perspective of reducing the vulnerability of that activity, but also from the perspective of minimizing the activity’s potential contribution to the hazard. Every development plan should incorporate elements of impact assessment, risk reduction and the ‘do not harm’ approach. All schemes for generating basic input data for hazard and vulnerability impact analysis should be taken up. Projects / schemes which yield multiplier effect for the greatest good of the largest number will deserve priority. Choice of appropriate technology, best practices and early warning system for disaster management. Stand-alone disaster management projects such as mitigation projects, awareness programmes, capacity building and CBDM projects, upgrading early warning systems, fail-safe disaster management communication network, micro-zoning and so on, to be taken up. Mainstreaming DRR into already approved projects in sectors of education, housing, infrastructure, urban development and the like. Some school buildings need to be identified which will be used as relief centres and buildings which should be so designed that they withstand the impact of disasters and also have adequate capacity to provide space as relief centres. Such schools should be equipped with essential services which assume great importance at the time of a disaster.

National Landslide Mitigation Project to strengthen the structural and non-structural landslide mitigation efforts and reduce the landslide risk and vulnerability in the hilly districts prone to landslides and mudflows. Expanded Disaster Risk Mitigation Project to strengthen structural and non-structural disaster proneness and mitigation efforts to reduce the risk and vulnerability
Mainstreaming Landslides Risk Reduction in Development

in the disaster prone districts with community participation. Information, Education and Communication (IEC) programme for disaster risk and vulnerability reduction, disaster preparedness, structural and non-structural mitigation efforts and disaster response by developing ICT materials, print and electronic media products, campaigns, exhibitions etc. India needs to adopt a proactive approach for providing necessary support to the neighboring countries through multi-lateral cooperation and involvement of regional organizations.

- Vulnerability Assessment Scheme - Gujarat has undertaken vulnerability analysis of different parts of the state to different forms of disasters. Such an analysis is urgently required to be carried out by other states too.
- National Disaster Communication Network (NDCN) for dedicated communication and IT support for proactive disaster support functions including early warning and forecasting.
- National Earthquake Risk Mitigation Project for strengthening structural and non-structural earthquake mitigation efforts and reducing vulnerability and risk in high risk districts.
- National Flood Mitigation Project has multi-objectives including effective preparedness and improved promptness and capability, strengthening community capacity, and reduction in consequences of floods.
- Completely new infrastructure to be built for 6 battalions @Rs.80 Crore per bn and existing infrastructure to be upgraded for the 2 battalions @Rs.25 Crore per bn.
- Micro-zonation of major cities to be carried out. The high risk cities in seismic zone V and IV to prepare strategies to reduce earthquake risk and vulnerability.
- NDMA/MHA to take mitigation projects for DRR and also undertake special studies and research programmes.
- NDMA got the National Policy on Disaster Management approved from the Cabinet on 22 October 2009. It has also issued more than a score of Guidelines on Landslides and Avalanches, Cyclones, Earthquake, Chemical Disasters, Drought, Urban Floods, Tsunami, Biological, Chemical (terrorism), Chemical (Industrial), Nuclear disasters and on role of Civil Defence, NGOs, Medical Preparedness, Incident Response System, Psycho-social Support, Training Regime for Disaster Response, Institutional Strengthening and Capacity Building for DRR, State Disaster Management Plan etc.
11.1 Model Town Planning and Landuse Bye-Laws

In recognition of the importance of a techno-legal framework for regulating the already built environment, the Ministry of Home Affairs (MHA), Govt. of India had constituted a national level expert group to recommend modifications in existing regulations to ensure structural safety. The group recommended modifications in the Town and Country Planning Acts, Landuse and Zoning Regulations, Development Control Regulations (DCRs) and Building Bye-laws and developed a set of Model Bye-laws which are technically rigorous and conform to globally accepted norms. They also prescribe regulatory, quality control and compliance mechanisms. MHA has circulated these Model Bye-Laws to state governments for review of the byelaws currently in force and for ensuring their adoption after revision. The state governments will review and adopt the Model Town Planning Bye-Law.

Bureau of Indian Standards (BIS) has finalized and published the following Codes and Guidelines related to landslide:

- IS 14458: Guidelines for Retaining Wall for Hill Areas  
  Part 1: Selection of Type of Walls  
  Part 2: Design of Retaining/Breast Walls  
  Part 3: Construction of Dry Stone Walls
- IS 14680:1999 : Guidelines for Landslide Control
- IS 14804:2000 : Guidelines for Siting, Design and Selection of Materials for residential buildings in Hilly Areas
- National Building Code (NBC) 2005

The Part 2 Macro Zonation dealing with guidelines for preparation of LHZ maps in mountainous terrain is under revision and the guidelines for LHZ mapping on meso-scales is under preparation.

It is felt that there should be codes/ guidelines in case of landslides risk evaluation and detailed geological investigations of landslides.

In case of hydropower projects in hilly terrains, all agencies involved, including those in private and public sectors, require to follow these guidelines for
preparation of LSM, LHZ and risk analysis maps and obtain clearance from the concerned authority before initiating the project.

### 11.2 Model Village Planning and Landuse Bye-Laws

To ensure structural safety on village level in mountainous terrains, a techno-legal framework, akin to town planning bye laws, needs to be developed which will translate and codify the landslide concerns into village development.

Appropriate legislation may be considered for enactment for future safe and planned development in towns and villages affected by landslide hazard.

Other than BIS, there are a number of other bodies that develop design codes and guidelines in the country, e.g., the Indian Roads Congress (IRC), Ministry of Shipping, Road Transport and Highways (MoSRTH), Research, the Designs and Standards Organisation (RDSO), Ministry of Railways (MoR) etc. Codes developed by these organisations should also be updated and made consistent with the current state-of-the-art techniques on landslide safety. These agencies also have a number of internal memos for regulation of construction practices, the review of which should also be undertaken.

### 11.3 Techno-legal Regime

The techno-legal regime for landslide risk management should cover both technical and legal issues for effective regulation, implementation and management of landslides risks.

All future developmental activities should be regulated by codal provisions which should have all disaster resistant features. Our country does not have any major provisions or good enforcement systems to take care of disaster resistant constructions for landslides. As is known, hazards do not kill people, it is the badly planned and/or adversely located structures that result in damage to property and life. This can be dealt with by adopting a techno-legal regime through introduction of disaster resistant planning features in the development and building regulations.

The DM Act 2005 has clearly defined the institutional and coordination mechanisms at national, state, district and local levels and provides for establishment of Disaster Mitigation Fund and Disaster Response Fund at national, state, and district levels. The Act also provides for legal powers and penalties. The provisions included in the act shall be valid throughout the country.
State Governments should update the urban and landuse regulations by making amendments to incorporate multi-hazard safety requirements. State Governments should review, revise and update the Town and Country Planning Acts, Landuse and Zoning Regulations, Building Bye-laws and DCRs, and this process will be repeated at regular intervals.

11.4 Licensing and Certification

All professionals dealing with safety aspects of slopes in hilly areas should be trained and sensitized through a capacity building process initially and certified through a licensing process. Such certification requirements, in accordance with the criteria evolved by the model techno-legal regime, will be incorporated in the DCRs. Engineering Geologists and Engineers working with the GoI and state government organisations should also be subjected to this certification.

11.5 Compliance Review

There is need for a sound compliance regime to ensure the effectiveness of legal provisions. It is most important that monitoring, verification and compliance arrangements are in place both at national and state levels.

All landuse and developmental plans in hilly areas will go through a mandatory compliance review by the professionals of ULBs and PRIs to which these are to be submitted for approval. The major projects and critical structures will be put through a mandatory compliance review by qualified external agencies.

The model techno-legal regime recommended by the expert group set up by the MHA, will be incorporated in DCRs to enforce the scrutiny of developmental and landuse plans in hilly areas for their compliance to safety in accordance with the requirements under the DCRs. This scrutiny will be applicable to all construction habitations and structures in both urban and rural areas. The state governments, in consultation with their SEMCs and HSCs, will ensure that the bodies responsible for compliance are equipped with qualified professionals to undertake general compliance reviews. These professionals, who may be government employees or accredited private practitioners, will be trained specifically in the compliance of the bye-laws.

The area selected for expansion of human settlements, industrial clusters and other important projects in hilly areas should be assessed regarding the status of slope stability by accredited agencies or professional for safety of these.
11.6 Technical Audits and Monitoring

All existing habitations and important structures located in vulnerable areas and facing high risk from unstable slopes should be monitored by the ULBs. The slope stability assessment reports and treatment requirements, if needed, should be scrutinised for regulation compliance as per the specifications of the model techno-legal regime. In case of major projects, these aspects should be subjected to detailed technical evaluations before granting the construction permissions.

11.7 Techno-financial Regime

After occurrence of a disastrous landslide, the central and state governments provide funds for immediate relief and rehabilitation. This process does not adequately cover the requirements for reconstruction of damaged structures and land especially those that are privately owned. Expenditure incurred by the GoI in provision of funds for relief, rehabilitation and reconstruction is increasing manifold due to the rapidly increasing risk profile of the country. In most countries, risk transfer through insurance has been adopted as a step towards providing adequate compensation for the loss of property caused by disasters. Such a mechanism reduces the financial burden of the government. Risk transfer mechanisms have been found to be fairly successful in some countries. Therefore, the insurance sector will be encouraged in our country also to promote such mechanisms in future.

Financial institutions should consider the compliance of safety aspects as far as slope stability issues are concerned before offering construction loans in hilly areas. The housing development programmes supported by the GoI and state governments (like Indira Awas Yojana), and all large-scale housing schemes will have to comply with landslide safety regime.

The approval and disbursement of funds from banks and other financial institutions to industrial units will also be linked to the compliance with slope stability norms by these units.

11.7.1 Financial Allocations for Landslide Management

Central and state ministries / departments will mainstream disaster management efforts in their developmental plans. Accordingly annual plans, specific allocations will be made for carrying out disaster awareness, preparedness and mitigation efforts. Corporate sector can also be collected for supporting landslide risk management efforts as part of Corporate Social Responsibility (CSR).
11.8 Integration of Landslide Management with Development Planning

- Creating a vibrant network of agencies and knowledge based institutions dealing with landslide studies for effective implementation of national landslide agenda
- Empowerment of multi-institutional and multi-disciplinary teams
- Switch-over from piecemeal remediation of landslides to holistic implementation of control measures
- Management of change from outmoded approaches in landslide remediation to landslide control by state-of-the-art technology
- Mobilization of private and Insurance sector participation.
- Streamlining of procedures for speedy funding of priority/fast track projects
- Switchover from conventional bureaucratic benchmarking and project progress evaluation to peer-centric progress review, evaluation and mid-course correction
- Seeding the concept of landslide prevention, and opportunity costs in administrative management of landslides

11.9 Recent Government Initiatives

GoI has constituted a number of Disaster Management bodies at national, state, district and sub-district levels to assess the hazard and the risk and to develop early warning systems, evolve techniques for hazard mitigation, generate public awareness about the causes, effects and safety measures to be adopted and to undertake rescue, relief and rehabilitation measures. At national level, the Ministry of Home affairs is the Nodal Ministry for coordination of relief and response and overall disaster management and Geological Survey of India, an attached office of the Ministry of Mines, declared as nodal agency for landslides by the GoI in January 2004. Accordingly an Action Plan on Landslide Hazard Risk Mitigation was formulated by MHA and GSI started its implementation. Subsequently, the National Disaster Management Act 2005 came into being on 23rd December 2005 and the government set up National Disaster Management Authority (NDMA), a statutory body under the chairmanship of Prime Minister as provided for in this Act. The responsibility to cope with natural disaster is essentially that of state government. The role of central government is supportive in terms of supplementation of physical and financial resources. At State level, each State Government has set up
Disaster Management Authority under the direct control of the Chief Minister. The Chief Secretary of the State heads a State level committee which has overall responsibility for the relief operations in the State. The Relief Commissioners who are in charge of the relief and rehabilitation measures in the wake of natural and other disasters in their States function under the overall direction and control of the State level committee. At District level, it is the Collector/District Magistrate/ Deputy Commissioner who exercises coordinating and supervising powers over all the departments at district level. For any natural disaster, the declared nodal agencies are responsible for coordinating/undertaking studies for processes responsible for hazard and suggesting precautionary and preventive measures, monitoring the disasters, developing early warning systems etc.

11.10 National Disaster Management Policy and Guidelines

National Disaster Management Authority has formulated a draft on National Disaster Management Policy. The present Policy envisages two tier measures which pre-disaster measures comprising preparedness, prevention and mitigation and post-disaster Measures comprising emergency response (rescue & relief) and rehabilitation. Unlike earthquakes and floods, landslides are rather localized and induced by some causative factors, which are well understood. This hazard can be very effectively controlled or reduced if initiatives and activities are based on the most modern technological and scientific approach and the policy implemented through a well coordinated institutionalized mechanism.

The approach to formulation of guidelines comprises a participatory and consultative process. The basic concepts of this exercise include:

- An exhaustive review, disaster-wise, of the actions/steps taken so far by various agencies including central ministries and departments, States, academic, Scientific and technical institutions, NGOs etc.
- Identification of the residual agenda in terms of operational, administrative, financial and legal issues.
- Identification of the destination, in terms of goals and objectives, to be attained, in the short, as well as long term, duly prioritized as vital, essential and desirable with timelines and milestones.
- Drawing up of a roadmap to destination duly indicating the milestones to facilitate easy monitoring.
- Putting in place an institutional mechanism that oversees the operationalisation of this roadmap.
NDMA will play a nodal role in initiating the institutional measures for prevention, mitigation and preparedness with a view to generate a holistic, integrated and proactive approach to Disaster Management.

The NEC, statutorily mandated to assist NDMA will be responsible for preparing the national plan based on the policy and guidelines. NEC will also be responsible for getting it approved by the NDMA and its operationalisation.

The National Disaster Response Force (NDRF) will play a pivotal role in specialized response to a threatening disaster situation or disasters. The general superintendence, direction and control of this force will be vested in and exercised by the NDMA.

At state level, the SDMAs, established by the state governments to lay down policies and plans for DM in the state will, inter-alia approve the state plan in accordance with the guidelines laid down by NDMA and coordinate the implementation of the state plan.

Landslide is a very significant natural hazard in the country which not only threatens environment, human safety, and infrastructure and post earthquake relief operations but also hugely impacts the national economy. It deserves much greater attention in terms of multi-hazard mapping, research, scientific investigations and effective mitigation and management practices. The Guidelines addresses varied aspects of landslide mitigation and management and adopts a holistic and integrated approach that maximizes the networking of voluntary agencies, affected communities and other stakeholders.
Sub-Module 12: Community Based Action Plan for Multi-hazard Risk Management

Lessons learnt from recent disasters have made it apparent that no strategy may be successful in disaster risk reduction until and unless the affected communities are made an integral part of the management process and come forward to act proactively for risk assessment, prevention, mitigation, preparedness and emergency response. The communities in Garhwal Himalaya suffered major earthquakes (Uttarkashi-1991 and Chamoli-1999), landslides and debris flow (Malpa and Ukhimath-1998, Phata-2001, Budhakedar-2002, Varunawat-2003, Lambagar-2004, Dhanaulti-2005, Dharchula-2006, Syaldhar-2007, Sukhidang-2008, Munsiyari-2009), flash floods (Alaknanda-1970 and Bhagirathi-1978), major forest fires occur almost every third year, hailstorms and lightning etc. Hence, they became very sensitive to such disastrous events that caused heavy loss of lives, economy and environment. Such losses are rising due to increase in frequency and severity of disasters and rampant unscientific developments in vulnerable locations. During the last one decade, the interventions made by the governmental and non-governmental organizations through various efforts like Disaster Risk Management Project by United Nations Development Programme and Ministry of Home Affairs, Government of India as well as pilot projects on disaster management undertaken by local community based organizations have built the communities’ capacity to prepare themselves against disasters and reduce the risks by appropriate planning, development and management at local levels. It is believed that an aware, informed and prepared community is better able to avert, prevent and react to disasters than otherwise. With this background, an effort was made to empower communities through training and field demonstrations to initiate local actions for multi-hazard risk management through the inhabitants of 50 villages in Rudraprayag District in Uttarakhand State, Garhwal Himalaya. The chapter elaborates the activities undertaken in developing the methodology for community based disaster risk management, the process of operation, the outcome and its sustenance.

12.1 Introduction

No part of the earth is free from natural hazards that adversely affect the life, economy and environment. But these hazardous events become catastrophic and termed as disasters when they strike any built environment & affect population
that is not prepared against these hazards. Thus, disasters of any kind may inflict the safety and quality of life in a society. Despite all the scientific and technological innovations, it has been difficult to reduce the impacts of these disasters. Governmental or institutional interventions for disaster management do not succeed due to lack of considerations for community dynamics, perceptions and priorities in local context. Rather the frequency and intensity of disasters appears to have increased due to rise in population density, occupation of hazardous areas, unplanned / fast developments, human fault and hostile actions, neglect of unforeseen hazards and so on.

Since most of our concerns are anthropocentric and relate to development of a sustainable environment for its survival, most hazards in remote and unpopulated areas are not cared for and all our efforts focus towards disaster management of populated and built areas. India’s most population (about 70%) lives in villages and hence, the present attempt is primarily oriented towards a rural community to reduce disaster risks.

Disasters are linked not only to hazardous events but also to the vulnerabilities of the exposed elements and capacities within the society to cope with them. Thus, there are three major operating factors that influence the degree of disaster in any area i.e. hazard factor (magnitude, frequency, time of occurrence, duration & extent), vulnerability of different elements exposed to hazards (degree/duration of exposure, proximity to hazardous sources, degree of vulnerability and its value) and the capacities (techno-economic status, socio-political system & coping mechanisms). The paper focuses on possible methods of hazard identification and assessment by the community in its locality, by virtue of their natural experiences with these disasters in the past / present that affect their lives, livelihood, livestock and living places.

A history of these disasters and their impacts on community, its resources and environment is recorded through a community meeting for spatio-temporal assessment of all the hazards and depicted in a sketch called community based multi-hazard assessment plan. The sketch shows not only the hazards (indicating the place and year of occurrence) but also the physiographic details, natural & social resources, infrastructure and community facilities. The second step in the approach relates to collection of information and data on different elements (physical, human, livestock, environment etc.) in a presentable form i.e. Tables or Charts, thus, providing an idea of degree of vulnerabilities of different elements to all the hazards collectively as well as individually. In the third step, capacities within the community in terms of skills, resources, knowledge & information to face or cope with the disaster are evaluated. These three steps give a very good assessment of the potential risks due to possible
disasters in any locality and an action plan is then prepared to prevent, mitigate or manage these potential disasters for reducing the risks / losses.

The planning strategy was then worked out on the basis of the aforementioned three steps. The fourth step (first in the planning strategy) makes an attempt towards hazard management i.e. to explore if the hazard can be avoided, prevented, mitigated, or monitored. The community looks for various options / alternatives that can be applied using the local skills, resources, knowledge and techniques. In the fifth step, an attempt to strengthen the existing vulnerable elements or reduce their degree of vulnerabilities through the use of anti-disaster or disaster resistant technologies will be promoted or encouraged. The last step, which envisages that despite all the efforts, disaster may continue to inflict upon the society, ensures that the community is aware and prepared to face the remnant disasters in a planned way rather than being caught suddenly in a rash manner. It assumes that an informed, aware and prepared community will be better able to cope with disasters than otherwise.

12.2. Why Community Based Disaster Risk Management?

The need for a Community Based Disaster Risk Management (CBDRM) can be highlighted by pointing out the shortcomings in the existing approach and stating the advantages of CBDRM.

12.2.1 Shortcomings in the existing approach

a. Same plan regardless of the regional characteristics is implemented / imposed everywhere.

b. Local / indigenous knowledge, experience, skills, resources and techniques are not given due importance. Rather external resources and techniques are proposed to be utilized.

c. Negligence about local cultural instincts and heritage.

d. Prioritisation is decided by an outsider and not the stakeholders or the community itself.

e. Local community does not have any information about the disaster management plans for their area and the role of different sectors in helping the community during disasters.

12.2.2 Advantages of Community Based Disaster Risk Management

a. Feelings of coordination and self belonging to the society are developed. As the plan is prepared in local laymen’s language, it is better understood by the community (including the illiterates).
b. Local geo-climatic and socio-economic characteristics get attention of the people in development and disaster management.

c. Local initiatives begin and community provides assistance to the executing agencies involved in disaster management.

d. There is exchange of knowledge, information, skills & techniques between the community and the experts involved from outside.

e. Community comes forward to put its ideas and suggestion for selection of appropriate programs suitable to their locality and society.

f. Community can keep a watch / monitor the quality of works being done in its locality. It will also generate a sense of responsibility among the community.

g. It will lead to capacity building of the community on issues of disaster safe developmental activities.

12.3. Development, Testing & Application of Community Methodology

The inception of the idea that CBDRM would be rational and beneficial for the society, led to development of a suitable methodology for use by the community in its aim to reduce disaster risks. Although several scientific and technological methodologies exist for hazard identification, assessment, monitoring and control; yet the community is barely involved or benefited by their application. Therefore, an attempt has been made to involve and use the community’s experiences and knowledge in dealing with the issues of disaster assessment and management while applying scientific principles of disaster management in a broader sense.

Basically, six steps were identified - three of which involve assessment of hazards, vulnerability and capacity within a locality and the other three steps deal with action planning for modification or management of the first three issues. A tool called participatory learning and action (PLA) was applied during development of the said methodology to make it practical and easier for the community to adopt,. The draft of this approach was taken to an interior village and discussed with the community there about its objectives and usage. The village community took keen interest in the proposed activity and carried out the whole task without much difficulty in less than two days at a community gathering. The results of this test were quite encouraging and hence, it was planned to extend the methodology to the community in other villages through a training of master facilitators from the members of task forces for disaster management in these villages.
The format of the methodology was designed in a way so that it can cover all the necessary steps in community based action planning for disaster risk management. However, the format was kept in an open style so that the community should be able to add or alter any information necessary to make it more effective and relevant as and when required. After drafting the plan, it was proposed that it should be presented before the community through a gathering of all the villagers and then tested and reviewed. The work plan and schedules of these plans were made available for public information. Further, the roles, responsibilities and operational procedures of the community members involved in planning, testing, review, implementation, monitoring and evaluation were also well defined.

12.4. Procedure for using Methodology for CBDRM

At the onset of this process, some key actions are required to be taken by the community to initiate the work in an organised and systematic way. It involves formation of task forces and supporting groups, their affiliation with village development committee, community mobilization and disasters related sensitization. In the present case, such task forces for disaster management were formed at village levels through Disaster Risk Management Programme of United Nations Development Programme (UNDP) and Ministry of Home Affairs (MHA), Government of India.

A dedicated village level disaster risk management committee should gather necessary information about disasters and their impacts in their locality to sensitize people through awareness campaigns. In order to involve the whole community in the process of disaster assessment and preparation of plan for disaster management, it would be essential that people are made aware about the impacts of hazards and need for preparedness to reduce losses. Community mobilization or motivation can be done through street plays, drama, songs, skits, posters, meetings, interactions, Sandesh Yatras (Message trips) and video documentaries etc. It should gain confidence among community and involve all the stakeholders in drafting, testing, review, monitoring, revision, implementation and evaluation of CBDRM plan. The following paragraph briefly explains this process.

12.4.1 Drafting the Plan

It involves the following activities:

- Disaster Campaign and Community Mobilisation / sensitization
- Information about locality, community and the environment
Community Based Action Plan for Multi-Hazard Risk Management

- Multi-Hazard Identification & Assessment
- Vulnerability and Capacity Assessment
- Risk Categorization and Prioritization
- Existing protection systems and safety / risk management plan
- Where are gaps in our protection and safety? - Identify what is not being done
- What options are available and what action can be taken? - Brainstorming alternatives

12.4.2 Testing and Review

- What is practically feasible and acceptable? Evaluate Actions
- Who else is doing this? - Coordinate with others
- How the implementation priorities will be set? - Define Action Plan
- Who administers the plan and implements actions? - Develop a Strategy
- How the actions will be done?
- When the actions will be started and completed?
- Monitoring and Evaluation scheme? - Adopt and Monitor

12.4.3 Implementation Strategy

Through the process of plan preparation, community determines the WHY, WHAT and WHERE of the plan; WHY damages occur, WHAT you want to do to achieve your goals, and WHERE in the community you want to implement the measures to reduce losses. To ensure that the plan will be implemented effectively, the following additional questions like WHO, WHEN and HOW should be answered.

WHO? Who will lead the implementation efforts? - Establish Implementation Committee. A committee responsible for managing the implementation activities must be assigned. It will be responsible for ensuring that project / plan continues to make progress. He should dedicate a significant amount of time to this task and should have the ability to obtain assistance from others.

WHEN? When will these activities be implemented, and in what order? A proper Implementation Schedule should be prepared defining top priorities, vital, essential and desirable actions with place, time and duration. Some activities may be implemented simultaneously. The following pre-requisites must be met to initiate ground actions.

- Identify all implementation tasks.
- Determine needed order of completion.
• Coordinate with other community activities and determine any special scheduling needs (e.g., seasonal climatic conditions).
• Determine start date and completion date.

HOW? How will community fund the implementation of envisaged actions. An appropriate budget and potential source(s) of funding should be identified. Identification of suitable technical and financial assistance sources is also important. Sometimes, the implementation of actions may require permits or approvals, which should be discussed at planning stage. The number of human resources, the time and skills required to execute the work should also be pre-determined.

12.5 Risk Assessment Process

It includes information population density / distribution, age distribution, mobility, vulnerable groups, and emergency resources etc. Environmental information includes water sources, climatic conditions, landforms, fauna and flora.

12.5.1 Compilation of Data / information related to Past, Existing and Potential Disasters

Before embarking upon the spatial assessment on a chart or a sheet of paper, it is advisable that a list of the past, existing and potential disasters that have affected or may affect the life, economy and environment in the locality is prepared. The list would serve as a basis for indicating the affected or susceptible elements and collection of necessary information on these disasters and their impacts on the community which will ultimately help in planning and management.

The planning committee can identify hazards in the community by using the following methods:

a. Involve the whole committee in the planning process.

b. Research the history of previous hazards in the community. Consult local historical records, old newspapers, local administration etc, for evidence of previous emergencies.

c. Ensure both ‘natural’ and ‘man-made’ hazards are identified. Be completely objective.

d. Brainstorm, using the complete planning committee, to ensure that no hazard has been overlooked.
e. Draw information from emergencies in other comparable communities and localities.

f. Consider hazards identified by higher level planning committees.

The output of this step is a list of hazards, including those which have no history of occurrence in the locality. List hazards randomly; do not attempt to rank them at this stage.

12.5.2 Preparation of Multi-hazard Risk Management sketch of the locality

Based on knowledge and experiences of local people, an attempt is made to depict the village boundaries, physiographic features, natural resources, social or individual resources, community facilities, infrastructure and hazards of all kinds. Such a sketch displays a very good picture of the resources, hazards and the development in the locality. Following steps are taken to achieve this goal.

i. Village territory (boundaries) and physiography (drainages, ridges, valleys, slopes, lake, ground cracks, landforms, rivers etc.)

ii. Natural Resources - Forests, Mines, Water sources such as falls, springs, lakes, medicinal plants

iii. Social / Individual Resources or properties - Human population, live-stocks, Agricultural fields, Cowsheds, Watermills, Open lands, Building sites, Houses, shops, factories

iv Community Facilities - Panchayat Bhawan, Community Centre, Temples, Schools, Society or govt. offices, Police Station, Forest Post

v Infrastructure / Basic Amenities - Roads, Hospitals, Electric lines, telecommunication (phones, WLL, mobiles, wireless, Post office), Water pipelines

vi List of disasters (past, existing and potential). All the information and data on the past disasters and their impacts are collected in a tabular form. The table provides the community a complete idea of the damages suffered by them in previous disasters and the degree of potential risks from future disasters. The details of lives lost, livelihood, resources, environment etc. are well illustrated through this exercise

vii Hazardous areas / Susceptible zones - indicate areas that are or may be affected by any hazardous event and put a symbol for that disaster e.g. landslide, earthquake, forest fires, hailstorms
viii Risk management features indicating existing preventive and mitigative measures, safe/unsafe shelters and routes, evacuation scheme, proposed development and disaster resistant features

Note: Mark north direction on the village sketch and use standard legends (wherever possible) for different features on the sketch.

12.5.3 Hazard Analysis & Disaster Sensitive Periods / Seasons

Hazard analysis is that part of the planning process which identifies and describes hazards and their effects upon the community. The analysis involves: identifying hazards; describing hazards (their frequency, distribution and impacts); describe effects (susceptible zones, vulnerable persons & properties, likely facilities and services to be affected and the potential problems), describing community and environment (vulnerability and capacity assessment); Prioritizing hazards; and determining planning objectives and scope for prevention, mitigation, preparedness, response and recovery. Hazard analysis provides the basis for emergency planning and arrangements.

Temporal analysis of the data on disasters will also reflect the vulnerable periods of the year that may be more sensitive to a particular disaster compared to other periods. Accordingly strategies for prevention, mitigation or preparedness can be planned.

12.5.4 Disaster History

Since most of the information get collected during the last step, the same can be used to write a history of disasters in the locality. The community can add versions of people’s experiences with the disasters and the lessons learnt or problems faced prior, during or after the disasters. This will be quite useful to record lessons learnt, good and bad practices as well as to avoid any mishappenings.

12.5.5 Vulnerability & Capacity Assessment

Vulnerability analysis is done by assessing the proportions of each group as part of the whole population, identifying any specific localities where there are concentrations of vulnerable people or other elements, e.g. schools, temples, in proximity to a hazard source. For each group identified, problems which might be expected under emergency conditions are noted. Community information also provides data on those groups in the community that have specialist skills or knowledge which may be useful in emergency management.
In order to bring a sense of belonging to the document by every individual in the community and to evaluate overall vulnerabilities and capacities, detailed information from each household / family should be suggested. The basic information gathered from each household include a reference to the households, the name of its family head, income levels and sources, age groups and physical / health conditions, skills / trainings in disasters management, emergency facilities and so on. Among the data on households, an attempt was made to identify insecure and vulnerable people who will need special and urgent attention in case a disaster strikes.

After an analysis of human and livestock vulnerabilities is completed, the next most important vulnerability concern is structural vulnerability of buildings. It is often seen that the impacts of disasters become high due to structural collapses particularly during earthquakes, landslides and floods. Thus, an attempt is made to collect data pertaining to vulnerability of buildings in the locality. It depends on the type of structure, year of construction (age of building), design and construction practice, and so on. Besides considering the vulnerability aspect, it also deals with the capacities within the structure that may be used for safety, search and Rescue during disaster times. A mention of emergency requirements during disaster times would be helpful.

Just like people and livestocks in households, prepare a separate list of vulnerable buildings so that utmost care can be taken of the people who are resident in such buildings or may get affected by damage or collapse of these vulnerable buildings. The list should be available at Emergency Resources & Operations Centre (EROC) and distributed to responsible members of the task force and supporting groups. It will help them to take quick actions in saving lives as the information would be useful in locating the potential structures that may suffer severe damages during a disaster.

The community can also prepare a sketch map showing the various life line and critical facilities as well as basic amenities available in the village or in the vicinity of the village that can be affected or utilized during a disaster. The contact details of the emergency personnel during emergency should be made known to the community.

12.6. Risk Categorization and Prioritization

Prioritising hazards enables a planning committee to concentrate efforts on those hazards which may have the greatest effect on the community. Prioritization can be assisted by using certain tools, e.g. ‘Matrix Analysis’, and ‘Hazard Scoring & Ranking System’.
Based on the cumulative risk determined on the basis of degree of severity of the hazards and the class of vulnerability of different elements, the various levels of risk can be defined as acceptable, tolerable, adaptable, and non-acceptable or intolerable risks. The categorization will also help prioritizing the focus of disaster risk management actions as vital, essential and desirables within a given span of time.


The procedure for use of CBDRM methodology involves application of the maps, information and data obtained through the process of risk assessment for management of risks / losses in the locality in a way so that disaster incidences as well as the impacts can be minimized.

12.7.1 Hazard Avoidance and Prevention Plan

It may involve the following activities.

- Hazard Zonation - Incentive Zoning and Performance Zoning
- Regulating Development Controls / standards
- Enforcement of Building codes/byelaws
- Promotion of Disaster Resistant Technologies
- Awareness and Dissemination of Safety Guidelines
- Awareness Campaign about hazards & their impacts
- Structural Mitigation Measures
- Non-structural or Regulatory Measures
- Loss Sharing Measures

12.7.2 Hazard Mitigation & Vulnerability Reduction Plan

Disasters that can not be avoided or prevented are considered for mitigation and vulnerability reduction planning. Activities, often long-term, which aim to reduce the impact of a hazard on vulnerable communities, and address the related vulnerable conditions and their underlying causes are known as mitigation. Mitigation planning may include

- Reducing the frequency, severity, duration, extent of hazards by various possible means
- Diversification of incomes / livelihood alternatives
- Food and Water security
Training for community in disaster planning and management
Disaster Resistant Housing programmes, Building Codes and Byelaws
Advocacy to government and community
Environmental protection

12.7.3 Preparedness Plan
The disaster preparedness aims to:

- Ensure that appropriate systems are in place to provide prompt and effective assistance to disaster victims.
- Prepare the community to handle the disaster in the first 48-72 hours or so when outside help has not reached and the local administration is itself affected by the disaster.

It includes Community awareness/education, disaster plans, training/test exercises, emergency communications, Evacuation plans, Public information, Warning systems, Resource inventories, Provision of special resources.

The planning committee will need to determine whether any specialist functions will be required to be performed in support of the main community plan. These functions may include medical, communications, search & rescue, welfare, transport, engineering, and agriculture.

12.7.4 Establishment of Emergency Resources and Operations Centre

- List of Skilled and Trained Human Resources in and around village
- Available Emergency Resources - List and Storage
- Information & Data on past, existing and potential disasters
- A copy of the community based disaster management plan, its schedules and progress with time
- Training materials for disaster management
- Active stockpiling of emergency resources (This approach for providing supplies usually is more effective than the massive, post-disaster influx of supplies. It also does not tie up capital on stocks that may have a limited shelf life or never be used)
- Facilities for collection and maintenance of disaster funds
- Disaster Reduction Day/Week Celebrations
12.7.5 Warning, Drills and Exercises

Methods used for disseminating the warning may include media messages, door knocks, community networks, audible and/or visual signals. Consideration should be given to warning special needs groups like deaf, dumb and blind.

a. The stages of evacuation which are: warning; withdrawal; shelter; reunion; and return.

b. Identification of: sites suitable as assembly areas; sites suitable as evacuation centres; evacuation routes between the above; organisations responsible for conducting and assisting with the evacuation; registration teams;

c. organisations responsible for arranging and coordinating transport; and

d. organisations responsible for operating evacuation centres.

12.7.6 Response Plan (with local capacities)

Response is the activation and implementation of operational systems which includes activating and staffing the Emergency Resources and Operations Centre (EROC), activating the communications system, collecting, processing, and disseminating information, alerting support organisations, preparing and disseminating warnings and other public information, activating liaison arrangements, coordinating and deploying resources and arranging outside assistance, and providing assistance to other areas. The response plan should include information on

- Reflex Action to disaster and information
- Emergency Communication and Transportation
- Search, Rescue, Emergency Relief & First Aid
- Safe / alternate routes for evacuation
- Safe Accommodation, Temporary Shelters with basic amenities like food, water, light, ventilation (air), communication, health facilities (medicines), sanitation etc.
- Security of private properties and weaker sections particularly young women
- Carcass disposal, disinfectant spray and immunization
- Consolation to the victims
- Rapid Damage Assessment and Relief Distribution
- Repair, Restrengthening, Retrofitting, Reconstruction, Resettlement, Rehabilitation, Recovery, Redevelopment.
12.7.7 Do’s and Don’ts

In order to respond properly to disasters, it is vital to know how to react to disasters. The task forces will identify these do’s and don’ts for each hazard and make the community aware and prepared with this information. In order to make it more effective, practical rehearsals can be conducted with different target groups for ensuring the right kind of response by all. The necessary information regarding this is available from the District Authorities and the State Emergency Operation Centre at free of cost.

12.7.8 Emergency Communication and Transportation Plan

Since immediately after the disaster happens, one need to communicate with others who can be at risk or who can help; communication strategy should be prepared to trigger the Incident Command System (adopted recently by Government of India for Disaster Risk Management). Most often, the routine communication systems fail during such disasters, therefore, alternative arrangements that can be depended upon during disaster should be made. Transportation is also affected during disasters. So it becomes difficult to reach to the victims in time. An alternative emergency route and conveyance method can be thought of for operations during such emergencies.

A list of important individuals, authorities and offices related to disaster risk management should be kept ready along with their names, designation, addresses (both official and residential), phone numbers, mobile, fax, email etc. in easily accessible manner.

12.7.9 Search, Rescue, and Relief

A separate group of people can be assigned the task for carrying out search, rescue and relief operation during any disaster. Persons with background in army, civil defense, home gaurds or police can be helpful in doing such activities. Nurses and medical practitioners can guide and help in emergency relief and first aid to the victims.

12.7.10 Evacuation Plan, Safe Accommodations & Sites for Temporary Shelters

Since a large population of the village may be affected during disasters, a sketch of the village territory showing safer buildings and sites should be prepared during plan formulation to indicate the places and the routes to the community to be used during disaster periods. The plan map should not only show the evacuation routes but also indicates the routes that may be used by outsiders.
for providing relief to the victims. The access route is connected to main road. The evacuation routes are normally the alternate footpaths leading to an area away from the vulnerable structures and susceptible locations.

12.7.11 Consolation Team

The consolation teams may consist of respected aged persons, religious priests, school teachers or community leaders. Generally, there is a panic and trauma during and after the disaster. Victims need to be properly consoled and inspiration from local known person gives them more solace compared to outsiders.

12.7.12 Disposal of Corpses & Carcasses

Proper disposal of dead bodies at the earliest possible time is essential to avoid outbreak of any epidemic in the disaster affected area. A group of persons may be assigned this duty and trained in proper recording and disposal of dead bodies, particularly from the inhabited areas.

12.7.13 Immunization and Infection Control

Due to large number of deaths and injuries during disasters, the potential of getting affected by any contagious disease are very high. To control this, a team should be dedicated to immunize people and livestock against possible diseases and those affected by such diseases should be treated under control and given a separate facility.

12.7.14 Water and Sanitation

Drinking water supply may be affected during disasters. The water may be polluted by sewerage damage or due to some other reasons. Necessary precautions should be taken to keep a check on water quality and in case it is found polluted, proper treatment of the water sources and supplies should be done. Any leakage of drinking water supply that may occur during disaster should be immediately checked. Proper sanitation should be planned around temporary shelters where large number of people may reside together temporarily.

12.7.15 Rapid Damage Assessment & Relief Distribution

Appropriate objective kind of rapid damage assessment criteria should be well set for assessing the degree of damages and distribution of relief to the affected people. A team consisting of reliable, honest and justified persons can be kept ready for this kind of work.
12.7.16 Rehabilitation Plan

This is the phase in which the community is back on the normal life process and in fact is fine tuning their resources to deal with other emergencies. They are thus also in a position to provide help to some other disaster affected area in the manner that they received help and assistance.

- Shelter Rehabilitation
- Livelihood Rehabilitation
- Psycho-social Rehabilitation

12.7.17 Recovery and Redevelopment Plan

Recovery is restoration of the community structure and facilities, and support provided to affected people. It may include providing short-term emergency accommodation, counseling emotionally-affected people, establishing and managing emergency financial relief schemes, repairing or replacing damaged public utilities, services, and assets, surveying and assessing damage to public and private property.

Rapid steps must be taken to establish a system of continuous contact with the families stricken by the disaster. A system of this kind makes it possible to:

- collect information on requirements,
- route instructions and information,
- distribute where necessary the means of survival (clothing, blankets, food, etc.).
- Transport and highway maintenance; communications and information,
- Water supply, food, means of survival,
- Sanitation
- Health,
- Public law and order.

The mid-term and long term recovery plan will include

- Relief and Compensation
- Repair, Restrengthening, Retrofitting and Reconstruction
- Resettlement and Relocation
- Loaning, Compensation, Insurance and Tax Exemptions

The redevelopment plan of the locality should include the lessons learnt from the disasters, thereby discouraging the bad practices and encouraging the good practices for redevelopment in the affected area.
12.8. Limitations in Implementation of CBDRM Methodology

The experience of local community can help in developing a formally structured information infrastructure. Implementing such a process, however, will not be so simple. It will take time and commitment on the part of all those involved because there are some sources of frustration that will need to be addressed before it can become a reality. For example, a recurring view was expressed by the village community that they had ‘heard it all before’ at various times, but nothing practical had ever eventuated. They are looking for a worked-through example that they can follow and the resources to do it. It can not be achieved in any meeting, training or workshop; it can only be achieved on the ground in a real-world situation. The lack of communication reaching both top-down and bottom-up at the village level was also seen as a major source of frustration, and consequently a major hurdle. For a process that is all about information and improving the effectiveness with which it may be disseminated and used, the sharing of information about the process is critical - and that depends on communication.

Another frustration revolves around a stated lack of coordination and cooperation between the people and agencies that should be working together to improve community safety. This was seen as part of the power and political processes that tend to build barriers, rather than bridges. Frustration also relates to the perceived lack of resources - human, financial and technical. This is probably a universal frustration for all disaster managers. Typically, they are allocated only limited resources as well as limited time because a vested senior group seem to hold a different view (a disaster is unlikely to happen during their term in office, so why spend too much money on a disaster management system that does not bring significant political/economic gains with it). This may be a simplistic and cynical view, but it seems to correlate well with reality. These are not just technical issues but also socio-economic issues. Fortunately, frustrations can be overcome through strong will and determination by the public, even those as seemingly intractable as the ones identified here.

These established foundations are very sound indeed, and provide an excellent base on which to build an appropriate and sustainable information infrastructure may address issues from the village level to the level of the district and beyond. There are undoubtedly frustrations and problems that will need to be addressed along the way; however, it is clear that the communities are committed to embarking on this journey for a safer sustainable environment.

Another limitation of CBDRM lies in the fact that the local knowledge at the level of community can not always be sufficient to assess large scale phenomena
especially if their origin lies away from the zone of perception of the community or if it results from an exceptional situation (e.g. flooding due to bursting of a landslide dam on upstream side of the community). Therefore, the logic of the concept should clearly indicate the possibility of integrating information received from outside the community (national / state / district level disaster warning centers), even if it is of scientific origin and not expressed in terms to which the community is used to, as another major contribution to the re-assessment of a hazardous situation.

12.9. Conclusions

The successful application of this methodology in more than 50 villages by the community itself is evidently a good indicator of the acceptability and practicability of the approach as well as its outcome in the forms of large amounts of actual data and information generated through the process. The approach seems more rational and context specific for socio-cultural as well as geo-climatic condition. Its participatory nature and learning dynamics helps in deeper penetration of the efforts among the community.

It is essential that local capacities be strengthened to assess and manage disaster risks as well as to utilize indigenous knowledge, resources, skills, information and ideas. The approach considers varied factors like age, gender, geographic location, caste, ethnicity, literacy, community structure / dynamics, local politics, economic disparities and decision making in this process. These factors when accounted in disaster risk management strategies and action plan become a great asset in execution and implementation at ground level by the affected community.

If the methodology is applied in other areas in a similar fashion, it will have, no doubt, a very large database on disasters and a culture of aware and prepared communities in all villages. The approach is open for further modifications to suit to specific requirements of any area / community as is permitted in any context specific approach. Technical and financial support from outsiders will further boost the efforts of these villagers in fully implementing their strategies for disaster risk management at local levels.
13.1 Research Issues

There are several important areas of research, which need to be addressed leading to standardization of investigation and operating procedures, more reliable LHZ mapping, vulnerability assessment and risk analyses, cost effective landslide stabilization, user friendly multi-hazard mapping, damage assessment and introduction of the state of the art technology. Considerable amount of research and development work is needed to develop basic understanding of various types of landslides in India, their causative factors and mechanisms of development with particular reference to anthropogenic factors.

13.2 Standardisation

Some Institutes and Organisations are carrying out both LHZ mapping and site specific studies of landslides. However, there is no uniformity in the methodology, selection of scale of LHZ mapping and usages of landslide terminologies. As a result, a lot of confusion has been created among the geoscientists. Standardization of the terminology and classification of landslides, thematic mapping scales and introduction of mapping methodologies for different scales will be accorded priority. Scientific and systematic approaches for site specific study of landslide and procedure of ground validation of LHZ maps are equally important, and so is the development of scientific approach of integrating landslide hazard into multi-hazard mapping. R&D activities will be intensified to standardize the terminology and classification of landslides, thematic mapping scales and to develop uniform methodologies for different scales. Scientific and systematic approaches for site specific study of landslide and procedure of ground validation of LHZ maps will be prepared immediately.

A research programme will be undertaken by the knowledge based organizations/institutes of our country for developing scientific approach of integrating landslide hazard into multi-hazard mapping.

13.3 Earthquake Induced Landslides

Improved understanding of earthquake-induced landslides will call for research on estimation of site effects in different geological and geomorphological...
settings. Research to enhance the understanding of reactivation of old and recent landslides and initiation of first time landslides triggered by earthquake will be encouraged. Other topics of research may include run-out effects of flow slides resulting from earthquake liquefaction.

13.4 Design of Surface and Subsurface Drainage Systems

In India the rainwater from the slide surface is generally drained out through surface drainage system comprising lined catch water drains, contour drain and chute drain (often cascading type). In absence of any data about the catchment characteristics of a particular slope, the design of these drains is generally done on the basis of expert knowledge. On the other hand the subsurface water management from the slide mass or distressed hill slope is rarely practiced in our country. As a result, some of the slides requiring only subsurface drainage arrangement for stabilisation are provided with other makeshift remedial measures triggering the slide instead of containing the slide. Moreover, there is no systematic approach or established mechanism to test the efficacy of the implemented surface drainage measure. Effort should be directed towards research and development of scientific and innovative design of surface and subsurface drainage systems, which are the most important components of landslide stabilization measures.

13.5 Instrumentation for Geotechnical Investigation

In the context of scientific research, geotechnical instrumentation is primarily needed to unfold the mechanism of a landslide, collect evidences and data for its reliable slope analyses and engineering and remove uncertainties by validating assumptions and checking efficacy of control works.

13.6 Development of Early Warning System

There are many major landslides located either along the busy road corridors or close to thickly populated townships / important civil engineering structures that require huge cost of treatment. Such landslides for early warning will be selected through a consultative mechanism in association with state governments and local bodies. Development of appropriate Early Warning Systems may be undertaken for such identified slides. Development of Early Warning System by real time monitoring of some selected slide may be undertaken with a view to firming up both the early warning technology and the early warning thresholds. Correspondence between rainfall thresholds and landsliding should be developed for selected areas based on in-depth scientific studies.
13.7 Landslide Dams

Dams generated by landslides are mainly reported in narrow valleys of mountainous terrain. These may cause devastation by flash floods due to sudden breaching. Barring some preliminary investigation of a limited number of such dams, systematic geotechnical investigation has not so far been attempted. Besides, there is no established mechanism by which the incidence of such dams can be reported to the appropriate authorities immediately after their formation. As a result the preliminary investigation can not be taken up immediately after their formation.

The following aspects of landslide dams can be taken up for R&D:

- Dam break analysis
- Methodologies for providing controlled outlet for dewatering the created reservoir
- Procedure of risk assessment
- Procedure for identification of potential sites of formation of landslide dams and monitoring technique.

13.8 Run-out and Return Period Modeling of Landslides

This is one of the most important fields of landslide studies where extensive R & D is required. The basic requirement for development of Run out and Return period modeling of landslides is to map all the slides, identify causes and mechanism of failure, establish correlation between triggering agents and initiation of slope failure, determine shear strength parameters of the slope forming materials, assessment of hazards, vulnerability and elements at risk etc. In some countries, like Italy, New Zealand, USA, this type of modeling has been done for individual slides but it could not be successfully done for a vast area affected by numerous slides in the absence of reliable historic landslide inventory database.

13.9 Emerging Concerns

Presently global warming and climate change are the most critical fields of concern that can have significant consequences on natural hazards including landslides and snow avalanche.

The “fragile” mountain systems in the country, where most of the landslides occur, are being exposed to increasing risks due to climate change. In the coming decades, the negative impact of climate change will be exacerbated if the mounting human-induced pressures and unplanned urbanization are not checked.
Whereas the whole range of issues connected with climate change including policies and operation strategies are beyond the scope of this document, unfolding consequences of climate change, insofar as mitigation of landslide hazards are concerned, deserve urgent attention. Rich global experience, especially on understanding and managing uncertain weather patterns and landsliding, glacial lake outbursts, landslide dam bursts and community-centric risk reduction measures for human safety, should help speed up our own programmes with innovation and added emphasis on landslide hazard mitigation, early warning and quick response to disasters and long term socio-economic risk reduction.

13.10 Priorities for R & D:

The R & D problems of importance are listed below. This is only suggestive and will be reviewed from time to time in the backdrop of emerging national priorities.

- Refinement of methodologies for carrying LHZ both on Macro and Meso scales to bring out a realistic picture of the hazard
- Systematic scientific methods of landslide hazard, vulnerability assessment and risk evaluation on GIS platform
- Integration of landslide hazards into user-friendly multi-hazard mapping; projection of multi-hazard risk scenarios.
- Revisiting past major landslide disasters for scientific post-mortem and documentation of lessons learnt
- Application of recent technological developments in the fields of instrumentation, remote sensing, software and communication technologies for landslide studies.
- Development of simple, quick and effective methodologies for assessing direct as well as indirect losses due to occurrence of landslides
- Quantification of environmental degradation, anthropogenic impact, cost of loss of land, agriculture produce, livelihood and traffic delays
- Establishing best practice examples of deterministic and probabilistic modeling methodologies for conducting detailed stability analyses of complex natural and man made slopes and active landslides
- Scientific design of surface and subsurface drainage systems, technology for their speedy installation and evaluation of their efficacy
• Development of innovative techniques for landslide control especially mechanized construction of complex subsurface drainage networks

• Development of light rugged geotechnical investigational equipment suitable for rugged and inaccessible areas

• Development of cheap and reliable instrumentation techniques for slope monitoring and installing early warning systems

• Systematizing the search and rescue operations and developing effective equipment for the same

• Development of simple and easy to install instrumentation and slope monitoring for real time early warning including early warning thresholds and criteria

• Developing a predictive understanding of landslide processes and triggering mechanism;

• Regional real-time landslide warning systems based on threshold values of rainfall; Real-time monitoring and establishing early warning systems in case of landslides that pose substantial risk to developmental gains;

• Developing methodologies for assessing the potential co-seismic slides.

• Fundamental mechanisms of earthquake-induced and earthquake-triggered landslides

• Remediation practices based on multi-disciplinary field investigations and suitable for local conditions

• Methodology for identification of potential sites for landslide dams.

• Fashioning landslide rescue operations to their typology

• Reservoir induced landslides, coastal landslides, submarine slumping and tsunamis

Besides, post-disaster scenario analysis and simulation modeling are extremely useful for undertaking long-term disaster management programmes and for strengthening preparedness, mitigation and response efforts against landslide hazard. Risk assessment and scenario projections require data for all landslide prone areas and major landslides located in different environs in different parts of the country affecting existing human habitations, environment, infrastructure and economic activities.
Emerging Issues

The quantification of landslide risk for a specified area requires detailed information for a number of factors, namely topography, geomorphology, geology, climatic conditions, landuse practices, land cover pattern, characteristics of slope forming materials. The reliability of landslide hazard maps will depend on the accuracy of base maps and the approach followed in their GIS based integration and subsequent validation. Freshly occurring landslides and the reactivation of existing and old landslides on account of earthquakes will be studied. The LHZ maps will be prepared based on advanced research studies carried out by knowledge institutions to include the earthquake induced landslides in areas with high seismic risk.

Studies will be undertaken to evolve procedure so that investigations, maps and drawings of landslide in different geographical regions of the country are easily available to users in the form that can be easily comprehended.

There is urgent need to develop mechanism to transfer the results of R&D efforts to public domain so that these can be utilized by scientists/technologists engaged in operations.

The success of all these efforts will depend on a prior presence of a system with streamlined procedures for speedy funding of priority/fast track projects. The mechanism for evaluation of project proposals, periodic reviews and final reviews will be integral part of the system.

13.11 Documentation

It will include preparation of films, manuals and other documents targeting various stakeholders to inculcate landslide safety by following land zoning regulations. State governments will provide landslide safety materials in multiple formats and languages, so that different groups of stakeholders can gather requisite information. This information will include specific details on the landslide risk and vulnerability of the states, landslide management basics and landslide risk mitigation for the safety of natural and built environment.

The state governments will assist subject specialists from academia and industry to prepare technical documents on landslides, which will emphasize technical specifications for expansion of human settlements in hilly areas and simple techniques for assessing landslide hazard in other areas. National and regional libraries and information centres will be encouraged to build repositories of technical resources (books, reports, journals, electronic documents etc.) related to landslides.
Generate and maintain a directory of landslide management professionals in India, containing their brief bio-data and make these available to users.

GSI along with other institutions will undertake the task of documenting the history of landslide studies and other related activities in India. A number of documents on landslide investigations that have been carried out in the past have now become difficult to access or are out of print. GSI will launch a special initiative to digitise these documents from various sources and save the archives on electronic formats in the data bank proposed for this purpose giving due recognition to the source.

13.12 Response Capability

Response to early warnings involve activating coping mechanisms (mainly for orderly movement of people away from risk locales, seeking shelter and safely securing assets) before a disaster strikes. In contrast, post-disaster response implies the wider range of relief, restoration, recovery, rehabilitation and reconstruction efforts in the aftermath of disasters. However, both are part of disaster preparedness and employ common emergency procedures. Warnings of hazard events must be issued with clear instructions about the most appropriate actions to be taken to avoid losses as far as possible. The success of early warning depends on the extent to which it triggers effective response measures and warning systems will include preparedness strategies and plans to ensure effective response to warning messages. The warnings trigger a variety of responses from different agencies at various levels, which must be coordinated. A number of governmental agencies, including various ministries, national disaster management institutions, municipal and local administration authorities etc. are responsible for coordinating disaster preparedness. People are more likely to listen and act upon warnings when they have been educated about their risks and warning-reaction plans are in place.

The management and control of the adverse consequences of future landslide incidences will require coordinated, prompt and effective response systems at the Central and State Governments, and especially at the district and the community levels in the areas affected by landslides. Since many components of response initiatives are same for different types of disasters, systems need to be developed considering the multi-hazard scenario of various regions in order to optimally utilise available resources.

Depending on the magnitude of landslide and scale of required response, the corresponding role players will be identified and mobilised at the district, state or national levels. Systems will be institutionalised by the DMAs, at various
levels, for coordination between different agencies like central government ministries and departments, state governments, district administrations, ULBs, PRIs and other stakeholders for effective post-landslide response.

The preliminary assessment of severity of the landslides is based on its magnitude and the amount of loss it inflicts on the infrastructural elements and habitations. Agencies like BRO/ State PWDs, State Directorates of Mining and Geology, Forest Department, Municipal/ Panchayat Body would immediately communicate information of the occurrence of a landslide along with preliminary details like its location, magnitude and damage caused etc. to the District Emergency Centre or District Disaster Management Control Room. This will help to undertake field observation for making an accurate assessment and follow-up actions.

The Disaster Management (DM) plans prepared by concerned agencies will incorporate detailed guidelines for their activities related to the impact of landslide. The response component of the DM plans will consider the rapid deployment of designated people, supplies and logistics to the site of disaster with function of each functionary clearly defined. The individual teams will be required to vacate the site as soon as their job is over because considering the nature of hazard during the rainy season it is possible that they may be required at another site within short duration. These plans will prescribe appropriate coordination mechanisms among all the agencies working in the affected areas.

13.12.1 Emergency Search and Rescue

The community in the affected neighborhood is always the first responder after any disaster. Experience has shown that initially over 80 per cent of search and rescue operations are carried out by the local communities before the state machinery and specialized search and rescue teams arrive. Thus, trained and equipped teams consisting of local people will be set up in landslide prone areas to respond effectively in the event of disaster.

Community level teams will be developed in each district with basic training in search and rescue. Training modules will be developed for trainers of community level search and rescue teams by district authorities with the help of the NDRF training institutes. The manpower employed by the organizations engaged in maintaining the roads located in hilly regions will also be trained in initial search and rescue operations and equipped with modern search and rescue equipments. On the ground, if required, the NDRF battalions will also assist the state government/ district authorities in training communities for which they will be sensitised. They will be further assisted by the Civil Defence, Home Guards, Fire Services and NGOs. State Governments will develop procedures
for formally recognising and certifying such trained search and rescue team members; they will also provide suitable indemnity to community level team members for their actions in the course of emergency response following a landslide disaster. Youth organisations such as the National Cadet Corps (NCC) and National Service Scheme (NSS) and Nehru Yuva Kendra Sangathan (NYKS) will provide support services to the response teams at the local level under the overall guidance and supervision of the local administration.

13.12.2 Emergency Relief

Trained community level teams should assist in planning and setting up emergency shelters, distributing relief among the affected people, identifying missing people and addressing the needs of emergency medical care, water supply and sanitation, food and temporary shelters etc. of the affected community. These teams should also establish communication with district authorities for arranging evacuation of stranded people, particularly for vulnerable sections. Members of these teams must be made aware of the specific requirements of the disaster affected communities. These teams may also assist the government in identifying the most vulnerable people who may need special assistance when stranded following a large landslide on a highway or in a habitation.

13.12.3 Incident Command System (ICS)

All response activities should be undertaken at the local level through a suitably devised Incident Command System (ICS) coordinated by the local administration through the EOC. State Governments will commission and maintain Emergency Operation Centres (EOCs) at appropriate levels for the coordination of human resources, relief supplies and equipment. Standard Operating Procedures (SOPs) for the EOCs will be developed by State Governments and integrated within the framework of the ICS, which will take advantage of modern technologies and tools, such as GIS maps, scenarios and simulation models for effectively responding to disasters. Geographical Information System (GIS) maps available with other sources, such as the district and municipal planning departments will be compiled considering their potential application after a disaster. Any unusual occurrence should be immediately reported by the community to the authorities, so that its cognizance is taken.

13.12.4 Community Based Disaster Response

The DDMAs should coordinate with the organisations, like NGOs, voluntary agencies, self help groups, youth organisations, women’s groups, civil defence, home guards and community at large who normally volunteer their services in
Emerging Issues

post disaster situations. The State Government/ SDMAs will utilize and allocate these human resources for performing various response activities as per their capabilities. State Governments will interact with these agencies to understand and plan their roles in the command chain of the ICS and incorporate them in the DM plans.

Large magnitude natural disasters draw overwhelming humanitarian support from different stakeholders. The relief and response activities carried out by such stakeholders will coordinate and comply with the norms prescribed by the appropriate authorities.

After disastrous landslide incidence, accurate information will be provided on the extent of the losses and the details of the response activities through electronic and print media. State Governments will utilise different types of media, especially print, radio, television, internet and Short Messaging Service (SMS) to disseminate timely and accurate information.

13.12.5 Role of Private and Corporate Sectors

The State Governments should facilitate the involvement of the corporate and private sector and utilize their services and resources if offered to the government during the immediate post disaster situation. IDRN should be maintained and updated regularly so that locally available resources are utilized effectively in case of emergency. The corporate sector, as a part of the CSR effort, can provide, inter-alia, the services of hospitals, power and telecommunication, relief supplies, search and rescue equipment, earthmoving equipment, and transport and logistics of movement of relief supplies. The IDRN is a live system and is updated every quarter both at district and state levels. These can be mobilised promptly at the time of emergency as a component of response. The state governments and district authorities will develop appropriate mechanism to receive and optimally utilise such assistance.

13.12.6 Specialised Teams for Response

The central government has set up ten NDRF battalions for providing rapid response to disasters. The NDRF battalions are provided with communication equipment like satellite phones for establishing continuous connectivity in every part of the country where landslide or other disasters may occur.

The fire services in the ULBs of various states are being used as an emergency-cum-fire services force. The fire service personnel will be trained adequately so that they can respond to different disasters promptly in addition to managing fires.
The police play a very important role after a disaster by maintaining security, law and order, assisting in search and rescue, and in transportation and certification of casualties. In case the landslide disrupts traffic for a longer duration, traffic police can play an important role by regulating and controlling the flow of traffic movement.

The Home Guards serve as an auxiliary arm of the police force and support the district administration in various tasks. The Civil Defence is being reoriented to assist in handling DM. Members of these organisations will be trained in tasks like search and rescue and evacuation, protection of assets in evacuated areas, and management of relief camps and aid distribution centres.

Training and implementation of emergency response should be planned keeping in view that type of rescue operations varies with the nature of landslides.

### 13.13 Trigger Based Categorisation

Ministry of Home Affairs, GoI, in consultation with GSI has developed a colour coded categorization of stages of landslide for triggering appropriate alerts within the Government machinery. Three colour (Red, Orange and Yellow) coded stages have been defined on the basis of dimension, location and damages caused by the landslide. GSI and other knowledge based institutions in coordination with state governments will take up the geotechnical investigation of the landslides falling within the high alert red category stage and suggest appropriate remedial measures. Landslides in this category are of large dimensions that are located over or in close vicinity of urban settlements or fairly large rural settlements inflicting heavy losses to human life or urban infrastructure. This also includes landslides that block busy pilgrimage routes during peak times resulting in hardships to thousands of pilgrims and landslides which result in blockage of courses of relatively large natural drainages with or without formation of landslide dams. The small or moderate dimension landslides located at the fringes or away from human habitation and causing limited loss/damage have been categorized under the medium and low alert, viz. yellow and orange. These shall be taken up by the district and state administration. GSI and other knowledge based organisation will provide assistance and train professionals on need basis to state government for geotechnical studies and remedial measures.

### 13.14 Emergency Logistics

Specialised heavy earthmoving equipment and search / rescue equipments are required immediately after a landslide to clear debris and to carry out
search / rescue of trapped people from huge mass of debris. A list of such equipment and suppliers of such specialized equipment should be compiled to enter into long-term agreements for their mobilisation and deployment in the event of a landslide disaster. India Disaster Resource Network (IDRN), which is a web based resource inventory of information on emergency equipment and response personnel available in every district, should be revised and updated every three months. A mechanism of deploying required equipment at a very short notice in case of occurrence of a disastrous slide should be in place.

The provision of providing temporary shelters and basic amenities for travelers stranded on communication routes would require pre-planning. The DM plans at the state and district levels should address this issue in detail. It is also being considered that semi permanent shelters with basic amenities would be established at certain critical locations that are affected by landslides frequently resulting in people getting stranded for long periods.

In the event of large number of casualties, respective states will develop systems for proper identification of the deceased, recording the details of victims and handing over the bodies to their kith and kin as quickly as possible.

13.15 Emergency Medical Response

In case of requirement, prompt and efficient emergency medical response will be provided by QRMTs, mobile field hospitals, ARMVs and heli-ambulances that will be in place for other disasters like earthquake. These will be activated to reach the landslide affected locations immediately, along with dressing material, splints, portable X-ray machines, mobile operation theatres, resuscitation equipment and life-saving drugs, etc.

The emergency medical plan will be operationalised immediately on receiving information from the landslide affected locations. Hospitals in the affected areas will create a capacity for the required number of beds by discharging non-critical patients and mobilize doctors and support staff, additional orthopedic equipment and supplies at short notice in landslide affected areas, at least during rainy season when majority of landslide occur. After the occurrence of a disastrous landslide, an Information Centre should be set up for disseminating accurate information to public, relatives of victims and media at district level in case casualties are high.

13.16 Loss and Damage Assessment

It is very important to assess the losses resulting from a landslide as this would be an important factor to decide whether it is economical to treat it or not.
Landslide-losses data are generally categorized as either direct or indirect. Losses can occur in a geographic region collectively (many, possibly intermingled, landslides that may affect lifelines and public safety, as well as individual buildings) or as a single, isolated event that affects a small geographic area, such as a highway or residential structures.

Direct costs include the repair, replacement, or maintenance resulting from damage to property or installations within the boundaries of the landslides or from flooding caused by breach of natural dam formed due to obstruction of natural drainage due to landsliding.

Some examples of indirect landslide losses are:

- Loss of industrial, agricultural and forest productivity and tourist revenues as a result of damage to land or facilities or interruption of transportation systems
- Reduced real estate values in areas threatened by landslides
- Loss of tax revenues on properties devalued as the result of landslides;
- Measures that are required to be taken, to prevent or mitigate additional landslide damage
- Adverse effects on water quality in streams and irrigation facilities outside the landslide area
- Loss of human or animal productivity because of injury, death, or psychological trauma; and
- Secondary physical effects, such as landslide-caused flooding, for which losses are both direct and indirect

Indirect costs may exceed direct ones; unfortunately, most indirect costs are difficult to evaluate and thus are often ignored or, when estimated, are too conservative. More often, however, monetary information, being of a discreet nature and in many instances, not in public domain, people and entities prefer to leave their losses as a private matter.

Currently, the damage assessment in case of natural disasters in many countries is done using aerial photography, videography and ground checks. With recent advances made in remote sensing technology it has become possible to use it effectively even for assessment of damages resulting from landslides. In order to be able to use Earth Observation (EO) data for landslide damage assessment, following criteria should be fulfilled:
• High temporal and high spatial resolution products should be available
• Images are taken at the time of disaster or within a few days after the event. These can support the relief efforts effectively

This will be satisfied partly by existing and planned high resolution stereo optical and SAR systems. In cases where damage is extensive, either by a single large event or by many large events spread over a large area, there is need of very high resolution images before and after the disaster. These can be used to supplement the data obtained from airborne and ground exercises.

13.17 Areas requiring special attention

• Effective management of landslide hazard in the country would require detailed studies using state-of-the-art technologies
• Introduction of the practice of real time monitoring of potentially threatening landslides, to avert disasters by early warning
• In the current landslide hazard management practice, investigating agency and implementing agency are generally different. This results in fragmented accountability and communication gap. Therefore, it will be ensured that the recommendations of the investigating agency will be implemented in close association or consultation with it
• Partial implementation of stability measures are understandably ineffective and in general, results in reoccurrence of landslide. Every landslide management project will ensure full implementation of treatment measures in a single working season and take recourse to monitoring of their efficacy during post implementation stage
• The process of data collection is required to be systematized. The system of data sharing among the institutions engaged in landslide studies, landslide hazard management and communities at large will be encouraged through effective networking
• The culture of observational method of design and construction will be promoted to help engineers and builders dealing with uncertainties effectively. The method helps in modulation of designs based on actual measurements as the work progresses
• Culture of monitoring the efficacy of control measures will be promoted to add to the confidence level in design and add value to it, if a situation so demands.
• There is lack of extensive network of rain gauges in country. Due to this it is very difficult to attempt the correlations between rainfall and landslide activity. A proper coordination with the IMD is required to be developed for installation of a network of automatic rain gauges at desired locations. The IMD will also provide daily rainfall data of existing rain gauges on daily basis to data center for landslides so that same can also be utilized by the agencies or individuals engaged in such studies. The concerned institutions will be identified.

• It is proposed that organizations/institutions engaged in landslide studies, government or private, should be identified/selected and given the responsibility for this work in co-ordination with the BRO and respective state governments.

• The resources and resource persons available in the country will be identified so that studies to be taken up in different fields are planned and realistic capacity building programmes designed.

• The gap between the landslide management systems being practiced in the country and those being followed internationally will be identified and attempts will be made by all agencies engaged in landslide hazard management in the country, to bridge these gaps so that latest systems followed elsewhere are also followed in the country.

• Establishment of a nation-wide institutional mechanism that would transform the current piecemeal, adhoc, less recognized and poorly appreciated landslide management practice into an organized vibrant pro-active, systematic and scientific routine.

• Enhancement of expertise and capacities of knowledge centres in different parts of the country for dependable and timely geomorphological, geotechnical and hydro-geological investigations and for scientific design and speed-effective implementation of control measures.

• Strengthening of a few objectively identified existing knowledge institutions or their units and departments in every state and union territory, if willing to redefine and enlarge their respective mandates/roles to provide/support pre- and post- landslide routine/specialized functions.
Training Programme on COMPREHENSIVE LANDSLIDES RISK MANAGEMENT
14.1 VARUNAWAT LANDSLIDE, UTTARAKHAND - CASE STUDY

Objectives of the Table Top Exercise

- To create sensitization about the landslide disasters.
- To assess the needs and capabilities to handle a disaster.
- To evaluate inter-agency coordination & gaps for improvement

Orientation / Preview

- Disaster Scenario (facilitator)
- Stakeholders
- Conduct of Exercise
- Observer’s & Evaluator’s comments
- Conclusion

Disaster Scenario

You have a landslide located along a national highway and very close to the district headquarter. The upper part of hill slopes fall under Forest Region and the lower slopes are occupied by private residential and commercial buildings, government colony and a mosque (community place). The slide area is evident by the exposed scar and the slide debris but the authorities are scared that it may pose a great risk to lives and structures located at foot-slopes. You are asked to assess the situation and provide adequate measures with action plan to prevent and mitigation the envisaged risks. How would you proceed ahead and tackle this situation?

Salient Features of Varunawat Landslide

Location: At km 150 from Rishikesh on Uttarkashi - Gangotri National Highway (NH - 108);
Latitude: 30° 44’10.8”N; Longitude: 78°26’23.0”E (Toposheet No. 53J/6);
Altitude: 1680m a.m.s.l.
Elevation: 1680 m (at Crown); 1170m (at road level); Relative Relief: 510m
Average Slope Gradient: 39°; Date of initiation of last major occurrence: Sept. 24, 2003

History of Slide: Not well recorded. Dates back to about more than 2 decades.

Recurrent slide

Type of Material involved in movement: Overburden, rock pieces / boulders of phyllites and quartzites - predominantly debris

Type of failure: Rotational (?) in upper part, Free fall followed by skidding, rolling, bouncing and sliding along three different tracks.

Direction of sliding / failure: SW on right flank, southern in the middle and SE on left flank

Area affected by failed slopes: approx. 2 sq.km. Population affected: 2,911

Landslide Precursors: Tilting of trees, development and propagation of new cracks, minor failure activities, rolling topography, presence of old cracks (widening and deepening), extension of old escarpment, increase in pore water pressure and seepage pressure, seismic vibration causing fatigue and failure of rocks, presence of old landslide zone, potential growth of some new plant species or younger plants in unstable / failing zones

State of Activity: Intermittently Active since last several years but continuously active for a period of about one month from Sept. 24 - Oct. 24, 2003; Style of Activity: Widening/Retrogressive

Depth of sliding: >20m; Volume of Displaced / Accumulated Mass (LxWxD): 15,000 cu.m. (?)

**IMPACTS:**

Economic Losses:

Damage to buildings - 364 (includes both residential & commercial); 63 houses damaged, 132 out of 364 were commercial buildings and 232 were residential or residential cum commercial (55 Kutcha and 175 Pucca buildings), people from 274 houses evacuated for safety.

Damages to Infrastructure (road, power, telephone and drainage lines) - A section of national highway (500m road), power supply lines and telecom facilities, traffic disruption

Economic Activities – 2,911 people lost their homes and jobs

Environmental Losses: Numerous trees uprooted, development of clouds of dust, pollution

Social Impacts: Closure of educational institutions for several days; Hindrance in social and cultural activities like Ramlila Program

Total Estimated Loss: Rs.300 Crores approximately
LANDSLIDE POSING RISK TO MULTISTOREYED HOTELS AT UTTARKASHI
(Photograph taken a day before these buildings were buried under this slide on Sept. 26, 2003)

Fig. 14.1: A view of landslide just a day before landslide engulfed the hotels seen here

Photograph after burial of hotels and other buildings at Uttarkashi

Fig. 14.2: A view of landslide on the day when landslide engulfed the hotels seen above
14.2 MALPA LANDSLIDE, UTTARAKHAND - CASE STUDY

Malpa Landslide Tragedy

Location: Right bank of River Kali, District Pithoragarh
On the fateful night between 17th and 18th August 1998, a huge mass of rock got detached, broke into myriad of pieces and hurtled down the slope. The rock avalanche killed 210 people including 60 pilgrims. The heap of debris so created were about 15m high and contained rock pieces as big as 5m. The estimated velocity was 30m/sec. Before the disaster, the hillslopes surrounding Malpa looked green, virtually without any visible sign of instability. In the landslide, the entire village was wiped out.

Disaster Scenario

A catastrophic landslide has occurred last night (1 am) at Malpa. Several pilgrims (who were resting at that site) are buried along with some local residents of the village. Most of the buildings at landslides have been destroyed and carried away by the slide and/or buried under the debris. The district headquarter is 100km away. You have received this report at 4 am from a villager. How would you respond to the situation?

Fig. 14.3: An artist’s recapitulation of rockfall area before the disaster (Courtesy -Dr. R.K. Bhandari)

Fig. 14.4: Photograph of rockfall area after the disaster (Courtesy -Dr. R.K. Bhandari)
14.3 GUINSAUGON LANDSLIDE, PHILIPPINES - CASE STUDY

Introduction

A rapid and long-traveling landslide occurred on 17 February 2006 in a rural area of Leyte Island, Philippine. The Landslide engulfed the Guinsaugon village including a church. The 4m deep landslide covered 3 square kilometer, killing more than 1,200 persons (154 fatalities and 990 people missing) and displacing 18,000 people. The estimated volume of landslide was $2.1 \times 10^7$ m$^3$. The horizontal distance from the top of landslide and the toe of landslide deposit has been measured to be around 4km.

The area had already been identified as risk prone and predictions of disaster had been made.

Timeline: Guinsaugon had been evacuated a week prior (on 10/2/06 due to heavy rains), but when rains temporarily stopped, villagers returned (due to a break in rains between 11/2/06 and 16/2/06) and became the victims.

- A very low magnitude earthquake of magnitude 2.6 occurred prior to slide.
- A slide occurred at 10am and recurred at 10pm.
- Mudslides blocked the tributaries of river and raised threat level of flooding.
Actions

S&R operations started within 3hrs of the disaster.
Relief efforts began including flying in response teams, tents, blankets, water, communication equipments, food, medical and psycho-social care
11 villages evacuated as preventive measure
PWD cleared road (blocked by slide) for relief operations
Flood warning issued to neighbouring areas
NGOs started coordination and relief operations
Landslide Experts arrived to determine causes and guide response / recovery actions (including a Japanese and Philippines joint team of 22 scientists and engineers)
Who's Doing What, Where, Database developed and monitoring commenced
Schools used as evacuation centres
Construction of housing in permanent relocation areas underway.

Situational Challenges (due to disaster circumstances, weather, topography, geographical remoteness etc.)

Debate over cause of slide: Illegal logging, heavy rains, small earthquake, planting of non-native coconut trees with shallow roots without adequate erosion protection
Landslide blocked roads so that only point of rescue was by boat from sea
S&R efforts were hampered because rescuers were in danger in the shifting mud, blocked roads, collapsed bridges and severed communication lines
Continued rains hampered relief efforts; tributaries blocked by landslide caused fear of flooding
Construction was considered time consuming due to lack of safe land and numerous official procedures for land acquisition
Rescue hampered due to threat of additional landslides
On the first day, area was accessible only by air
Unstable ground impeded movement of heavy machinery, rescuers had to dig manually making relief effort harder and slower.
Absence of light at night led to suspension of rescue on day-1 (the first 24hrs are critical in saving lives)
Heavy clouds impeded the arrival of helicopters; more rain fall in the next 48hrs after disaster
People were buried upto 40m deep in mud; it was hard to rescue them
Cracks were seen in the area where slopes have failed.

**Internal Resources or Infrastructure Challenges** *(logistic, financial, personnel, physical, technological, informational, infrastructure resources constraints)*

- Vulnerable buildings and siting conditions
- Scale of destruction hampered efforts
- The closest airport became congested due to numerous flights arriving for relief. The distance to airport with respect to disaster area more (flying time and time to travel by land to reach site was also more)

The evacuation centres were overcrowded, compounded by poor water/sanitation facilities, with inadequate number of latrines, no proper disposal of garbage & waste, poor supply of water for bath and cleaning, children and women were uncared
Lack of political will during relief effort slowed the government response
Large number of organization involved in response complicated the relief effort.

**What Went Right?**

More efforts to coordinate relief organizations to make operations effective
Efforts to learn from disaster to prevent and respond better to future disasters
Technology like thermal imaging equipment, canine units was used to make rescue & relief effort more effective
Latrines were designed in consultation with locals.

Who’s Doing What and Where Database made to coordinate efforts and prevent duplication

Specialized task forces formed for coordination and focus on logistics, supply management, environmental health and children in emergency

Surrounding susceptible areas were pre-emptively evacuated to avoid any further sufferings

**What Went Wrong?**

The need assessment took several days to complete and the results were not shared timely, affecting SRR efforts

Not enough effort was made to prevent the disaster. Although the danger was recognized in advance but the government failed to act in time.

When the area was evacuated prior to disaster, the residents did not clearly understand the magnitude of danger or when they should return. However, pre-emptive evacuation was a good move, it was not supported by instruction when to return.

Sphere standards of relief were not followed.

**Lessons Learnt**

An assessment should be made in such areas where landslides are common, regarding the ground condition to determine if it is safe for people to stay or they should be evacuated. The residents in Guinsaugon had returned because rains had stopped and it was ill considered safe to return, but no-one made an objective assessment of the area. An expert should have been in-charge of advising when to evacuate and/or when to return.

First 24-48hrs after disaster are important and critical for survival of victims. It was hampered due to bad weather and road conditions.

Establishment of a permanent relief centre close to disaster prone areas (but not so close that it may also be subject to damage during disaster) would accelerate the response. An effective layout for the centre to access the goods and supplies for SRR.

Technology and timing are two logistic strategy foci that work effectively. There should have been an agile strategy to meet the immediate and changing demands of SRR.
NGOs are critical to relief efforts. They are more local, on the ground, continuously carry out needs assessment and are able to adjust their response based on latest needs. They are also able to build on existing connection in communities and quickly obtain funds.

It is important to share the learning from each disaster so when disaster strikes again, the response improves.

Predisaster trainings on community based disaster preparedness in pre-identified areas by NGOs helped the disaster response.

Socio-psychological services need to be continued to help residents cope and heal from their incredible loss.

Medium and long term plans should include relocation, community based disaster preparedness, continued psycho-social support, construction of houses and community facilities, and livelihood programmes.

**Players / Actors / Stakeholders**

Civil Administration  
Red Cross  
Local Government  
Mines & Geology Department  
SDRF  
Army / Police / Civil Defence / Home Gaurds  
NGO  
Locals  
National and International NGOs  
UN Agencies: OCHA, UNDP, UNICEF, UNDAC
The drafting of the training module involved extensive consultation of research papers, books and reports published by many individuals and institutions / universities / organizations in India and abroad. Some of the consulted reports are listed below. Authors, compilers and editors of the documents consulted are gratefully acknowledged.

Anderson M.G. and Richard K.S., 1987: Slope Stability (Chichester: John Wiley & Sons Ltd.)


Dikau R., Brunsden D., Schrott L. And Ibsen M.L., 1996: Landslide Recognition-Identification, Movement and Causes (Chichester: John Wiley & Sons Ltd.)


Glade T., 2004: Vulnerability Assessment in landslide risk analysis, Die Erde, 134, 121-138


McGuire Bill, Barton Paul, Kilburn Christopher and Willets Oliver: World Atlas of Natural Hazards


National Disaster Management Guidelines, Management of Landslides and Avalanches, National Disaster Management Authority, Government of India, 2009


UN-ISDR Global Survey of Early Warning Systems, United Nations, 2006


Web Resources for Videos related to Landslides

**What are landslides and how are they caused?:** This clip explains the chain of events that causes mudslides. Taken from the show “When nature strikes back: landslides” available on FirstScience.tv.

Download in full from: [http://firstscience.tv/landslides.htm](http://firstscience.tv/landslides.htm)

[http://www.youtube.com/watch?v=HiNwmj5ALZs&feature=player_embedded](http://www.youtube.com/watch?v=HiNwmj5ALZs&feature=player_embedded)

*When Nature Strikes Back: Landslides (Full Program)* [http://www.youtube.com/watch?v=Vd7eHG2b_tQ&feature=related](http://www.youtube.com/watch?v=Vd7eHG2b_tQ&feature=related)

**Landslide hits east Cairo shanty town in Egypt:** A massive rockslide has hit a crowded Cairo shanty town, sending rocks and boulders crashed down onto dozens of houses.

[http://www.youtube.com/watch?v=uCDhtWH6t4&feature=player_embedded](http://www.youtube.com/watch?v=uCDhtWH6t4&feature=player_embedded)

**Raw Video: Dramatic Mudslides in Italy:** Around 200 residents of a southern Italian town were evacuated after an enormous landslide split the side of a hill.

[http://www.youtube.com/watch?v=zl7_OMqOZbo](http://www.youtube.com/watch?v=zl7_OMqOZbo)

**Dramatic amateur footage of deadly mudslide in Colombia:** Rescue workers resumed their search and rescue efforts after up to 30 people were buried by a mudslide near the town of Giraldo in northwestern Colombia. Authorities had reported that the strong rainy season caused flooding and made many roads unusable across Colombia. The magnitude of the mudslide was making rescue operations very difficult. Amateur video shows the slide as it tumbled down, wiping out several homes.

[http://www.youtube.com/watch?feature=fvwp&NR=1&v=BKTG58Bpziw](http://www.youtube.com/watch?feature=fvwp&NR=1&v=BKTG58Bpziw)

**Mudslide Vancouver Hope BC June 29 2011 Canada:** An extensive mudslide has Highway 1 closed in both directions at Popkum Road in the Hope area. The slide happened approximately 100 meters from the Herring Island exit this morning. It measures 25 feet deep and 200 feet long. Search and rescue crews had little to show after a ground search of a 60-metre wide mudslide on the Trans-Canada Highway between Chilliwack and Hope. In June 2000, a mudslide ripped the same stretch of highway between Chilliwack and Hope. No injuries were reported and both westbound and eastbound lanes were cleared within a
day. In January 2002, a more devastating mudslide -- provoked by a winter storm -- struck the Trans-Canada Highway and surrounding areas in Hope and Chilliwack. According to previous reports, the storm and ensuing slide caused hundreds of thousands of dollars of damage to roads, homes and businesses in the area.

http://www.youtube.com/watch?v=S0kKtmkMgJM&feature=related

Raw Video on Mudslides Destroy Homes in Bolivia: A mudslide swallowed at least 50 houses and displaced 600 people in Bolivian capital La Paz. The landslides were caused by the presence of subterranean water.

http://www.youtube.com/watch?v=EzOk_lxk4Ww&feature=player_embedded

Mudslides, Flooding Kill 84 in Brazil: After days of heavy, flooding rains throughout Brazil, it is mudslides that rescue workers are now fighting against. Dozens are dead, another 30 remain missing. Officials estimate 54,000 people are displaced from their homes.

http://www.youtube.com/watch?v=HA7YtAojmU0&feature=relmfu

Frank Slide: Largest Landslide in History

http://www.youtube.com/watch?v=B-C3MC1I1H7A&feature=related

Giant Sink Hole/Landslide Caught On Camera In Canada: This footage is from around Ontario, Canada.

http://www.youtube.com/watch?v=fbKDgF8CvmQ&feature=related

Massive Landslide Caught on Tape

http://www.youtube.com/watch?v=XC9AqJlaCj4&feature=related

Landslides in Svizzira, Switzerland http://www.youtube.com/watch?v=zGHCiXWR4DE&feature=relmfu

Quick Clay Landslide at Rissa - 1978 (English commentary) : On the 29th of April 1978, a quick clay landslide devastated large areas of the rural district of Rissa I mid-Norway. One person died whilst 13 farms; 2 homes; a cabin and a community centre were taken by the clay masses.

http://www.youtube.com/watch?v=3q-qfNIEP4A&feature=related

Raw Video: Deadly Landslide Hits Train in Italy - A landslide hit and derailed a train in northern Italy on Monday, killing 11 people and leaving some 30 injured.
Web Resources for Videos related to Landslides

http://www.youtube.com/watch?v=ktxDjqQlouw&feature=player_embedded

Raw Video: Landslide Kills 6 in China - A landslide in China’s southwest killed at least six people and damaged a bridge that is a key link for reconstruction in areas hit by a devastating earthquake.

http://www.youtube.com/watch?v=3nAlQxOrQxs&feature=relmfu

Raw Video: Landslide Buries Chinese Village: A state media report says a massive landslide in northern China partially has buried a village and killed at least 23 people, and that rescuers are seeking survivors.

http://www.youtube.com/watch?v=mxoAUG9nmhE&feature=related

Tibet to Nepal road with landslides - freaking scary 2: This is the continuation of my other video post "Tibet to Nepal road with landslide - freaking scary" where you can actually see the landslide "live". Bulldozer to the rescue, then continuing on, stumbling upon other landslides,

http://www.youtube.com/watch?v=weGGWdw7UHc&feature=related

Landslides in La Rinidad, Benguet Particularly in Buyagan and in Puguis: Landslides In La Trinidad, Benguet Particularly In Buyagan and In Puguis During Typhoon Pepeng, This Devastating Disaster Have Claimed Many Lives, Most Are Them Are Families and Only Few Survived.

http://www.youtube.com/watch?v=PFAGPYbgqlM&feature=related

Huge rock slide into lake! - shatters in half on the way down,

http://www.youtube.com/watch?v=xGzU_sQrMsk&feature=related

Half Dome rock fall, 5/27/11, Yosemite Valley: from top of Washington Column. Large blocks came all the way down the Death Slabs - would have been fatal for anyone approaching the NW base.

http://www.youtube.com/watch?v=MQvNm-Swdb8&feature=related


Giant Landslip hits village. Caught live on camera - Movie of an giant Landslip hitting an village in Italy

http://www.youtube.com/watch?v=MQvNm-Swdb8&feature=related
Rock Slide As It Happens - Coffee Creek - Kootenays: TMTV News - Nelson BC Canada (UNEDITED) A rock slide as it happens on Highway 31 at Coffee Creek north of Nelson BC closed the highway for several hours. Boulders come crashing down onto the highway while filming.

http://www.youtube.com/watch?v=B4RYtNJpdlY&feature=related

Huge rockfall on Mount Rainier: Smaller and larger rockfalls happened during the day about hourly. Around 4pm a huge part of Nisqually Cleaver fell down, creating a fast river of rock and snow.

It was the biggest that day.

http://www.youtube.com/watch?v=fzRhLs5GkYs&feature=related

Malaysia Landslide: landslide occur at Seaside Malaysia on 1993 year, this video was taken on the spot at that time. That year, I received a call by the owner of a tin mine (the element tin, not tin as in cans...). He said that his mine, which had been running for a few decades, was about to collapse. I rushed to the scene with my video camera and waited for a few hours. Finally, I took this valuable footage. Although the footage lasted only a few minutes, it is horribly exciting enough. I hope that this video can let you all appreciate the consequence of ruining our environment."

http://www.youtube.com/watch?v=H6Ma0SVjMHA

http://www.youtube.com/watch?v=hMnAfY5H-8E&feature=player_embedded# (link to TV program in USA )

Extreme landslide caught on camera VIDEO: http://www.youtube.com/watch?v=kNrmczkpcPU&feature=related

Raw Video: Many Missing After Mexican Landslide: Rescue efforts continued on Wednesday in a town in Mexico's Oaxaca state, after the area was hit by landslide caused by torrential rains.

http://www.youtube.com/watch?v=yZUxIfGtlT4&feature=player_embedded

Italy 16.02.2010: Impressive landslide caught on video - Italien Erdrutsch auf video - Italy http://croazia-alloggi-privati.info


The landslide, which caused power failure, could have been caused by heavy rains in the region, initial reports say.
Web Resources for Videos related to Landslides

http://www.youtube.com/watch?v=R__3DYQCvAa&feature=related

Heyelan - Land slide

http://www.youtube.com/watch?v=F3iywRvtNkY&feature=related

Heyelan-Land Slide 2

http://www.youtube.com/watch?v=KmjcBb_tR2k&feature=relmfu

Land Slide-Heyelan-3

http://www.youtube.com/watch?v=9ml-TAL6SDc&feature=relmfu

Destroyed in seconds, The Frank Slide - 1903- The community of Frank NWT is obliterated on April 29, 1903

http://www.youtube.com/watch?v=cb_0D1epHcU&feature=related

Awesome Landslide: Glad you weren’t driving on this Tennessee road when the cliff came down

http://www.youtube.com/watch?v=LeaX0ueZD-g&feature=related

Outrunning a Landslide: In Portland, Oregon, two men find themselves battling for their lives as a landslide hits their vehicle... and pushes it down the side of a mountain. They have to outrun the deluge of dirt and mud in order to survive. (from Discovery Channel’s “Against the Elements”)

http://www.youtube.com/watch?v=K1qY8nPqcCw&feature=related

Mount St. Helens Disintegrates in Enormous Landslide: Is any distance away from a volcano safe? Find out when an eruption causes one of the largest landslides in recorded history on Mount St. Helens. Unbelievable footage is studied and explained. (from Discovery Channel’s "Raging Planet")

http://www.youtube.com/watch?v=UK--hvgP2uY&feature=fvwrel

Landslide Repair: The machine has arrived to repair our landslide that happened in January. The “spider” handled the 25 foot drop with little problems.

http://www.youtube.com/watch?v=O_XIXeL1Tdw&feature=related

!!Landslide In California!!

http://www.youtube.com/watch?v=pCMMwQmUjHI&feature=related
Oliver Mudslide: Six families are homeless, after a massive wall of mud, water and debris rushed down a hillside just south of Oliver, in the Southern Okanagan. Homeowners heard the roar of the hillside giving way, and went door to door. Amazingly everyone got out alive -- and no one was injured. Emergency technicians surveyed the damage, and with rain in the forecast, they're concerned more slides could be triggered. Highway 97 is buried in meters of mud, and is expected to be closed for days. Homeowners affected by the slide will receive money from the Provincial Government's Disaster Assistance Plan.

http://www.youtube.com/watch?v=6YA1W4z_3kg&feature=related

Mudslide - June 2 2011, Keystone Colorado

http://www.youtube.com/watch?v=CyY3bCV8K-M&feature=related

Varunawat Land slide in 2003: Varunawat landslide clip, Uttarkashi

http://www.youtube.com/watch?v=IamLdh2O8lw&feature=related


http://www.youtube.com/watch?v=Z95nQw6Tzio&feature=relmfu

Live Landslide at Manali - Leh Highway: The landslide occurred between Sissu and Kokasar in the Manali-Leh Highway. Huge pieces of rock started falling from the cliff above.

http://www.youtube.com/watch?v=6Hi_Osg2dY4&feature=related

Landslide shot live near Dalhousie: Very recent landslide shot live while coming down from Dalhousie. this is about 15 kms down from Dalhousie enroute Pathankot. while we reached a small part of the mountain had fallen completely disrupting traffic and rendering them immobile. while I stood there, there was this whole mountain which came sliding down and honestly it was a lifetime experience bringing in mixed feelings of surprise...joy...and fear...the roads are albeit good such things keep on happening during monsoon...keep visiting Dalhousie...it makes for an exciting holiday.....no tie up with Himachal tourism...:-))

http://www.youtube.com/watch?v=Vc6ouosXk0Q&feature=related
About the Author

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Surya Parkash is a Ph.D. in Earth Sciences with specialization in geohazard risk management from the Indian Institute of Technology Roorkee. He did postgraduate studies in geology at the Central Building Research Institute – Roorkee, India, and New Delhi, India. He has worked with organizations like the National Institute of Disaster Management, India, and the National Disaster Management Authority. He is currently an Associate Professor at the National Institute of Disaster Management, Ministry of Home Affairs, Government of India.

About the Module

The module is designed as a comprehensive document that would help in training and capacity development for landslide risk reduction. It encompasses the experiences, information, and lessons learned by the author and other experts in the field. The module also provides a comprehensive strategy for landslide risk management using available tools and techniques. It is targeted towards an interdisciplinary and cross-sectoral approach.