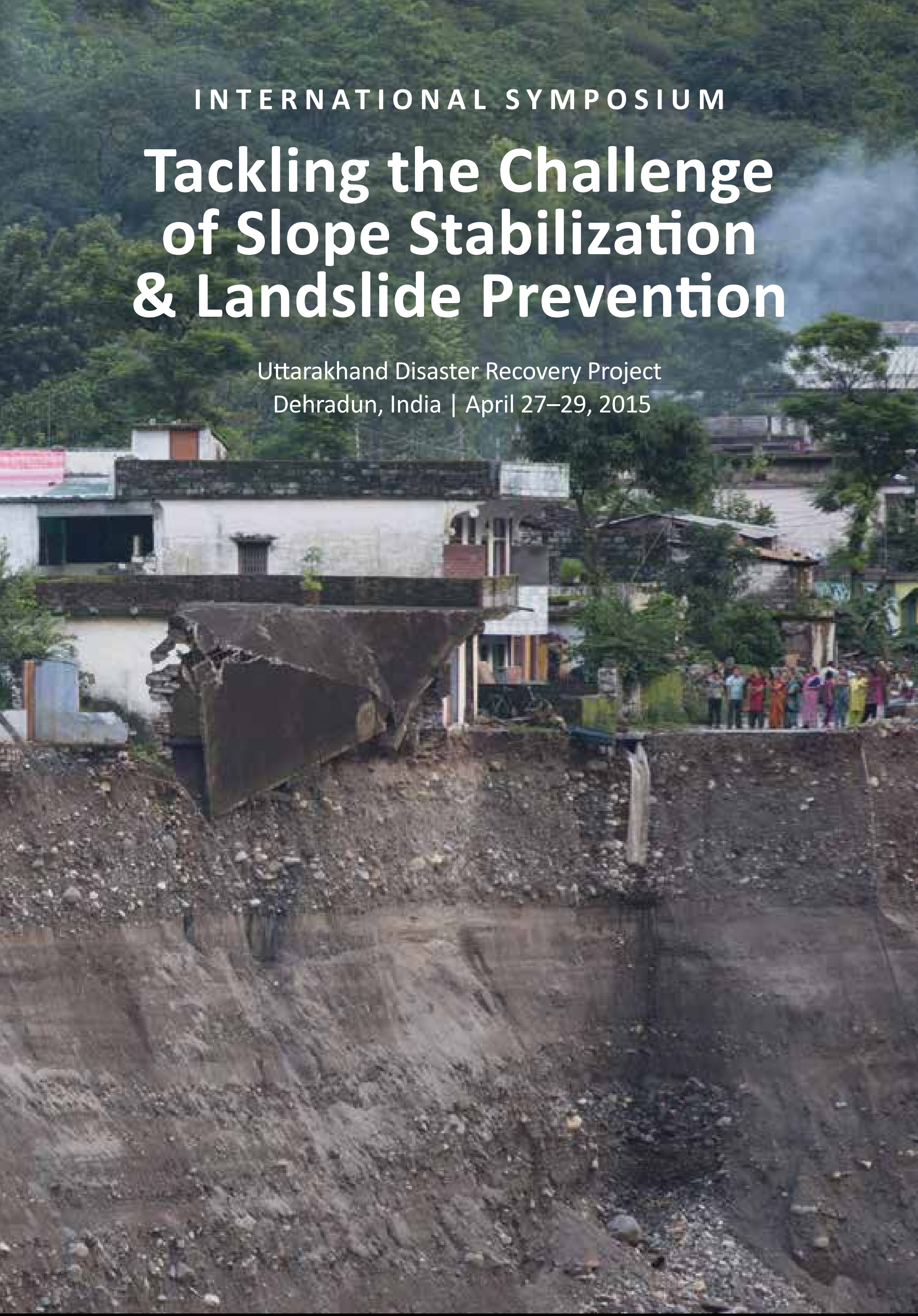

INTERNATIONAL SYMPOSIUM

Tackling the Challenge of Slope Stabilization & Landslide Prevention

Uttarakhand Disaster Recovery Project
Dehradun, India | April 27–29, 2015

FINAL REPORT

With support from:

ABBREVIATIONS

DMMC	Disaster Mitigation & Management Centre
EWS	Early Warning System(s)
GFDRR	Global Facility for Disaster Reduction and Recovery
GPR	Ground Penetrating Radar
JICA	Japan International Cooperation Agency
PWD	Public Works Department
SoR	Schedule of Rates
UDRP	Uttarakhand Disaster Recovery Project

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Cover photo credit: Red Cross
Back cover: Bridge over the Tehri dam reservoir. Photo credit: Wikimedia Commons
Road to Kedarnath, circa 2012. Photo credit: © Nila Newsom | Dreamstime.com

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Devprayag, Ganga’s birthplace—confluence of the Alaknanda and Bhagirathi rivers. Next page: Shri Kedarnath.
Photo credit: Thinkstock.com

FOREWORD

The state of Uttarakhand, often referred to as "Devbhoomi" meaning Abode of Gods, is blessed with a treasure of pristine scenic beauty in the form of lofty snow clad peaks of the Great Himalayas, glacial lakes, myriad of waterfalls, lush green meadows (Bugyals), perennial streams, dense alpine forests and rare species of fauna and flora. The State is home to two of the most sacred rivers of this country, Ganga and Yamuna and houses holy shrines of Yamunotri, Gangotri, Shri Badrinath, Shri Kedarnath and Hemkund Sahib.

Carved out of the erstwhile Uttar Pradesh on 9th November, 2000 Uttarakhand is in a nascent stage and faces scarcity of resources together with many challenges that are primarily owed to rugged terrain, inaccessibility, large forest cover and inhospitable weather.

Pilgrimage, tourism, trekking, mountaineering and adventure sports together constitute a major source of revenue for the state besides providing employment to the masses. The potential of this sector is however far from being fully harnessed and better connectivity and infrastructure could greatly boost the income from this sector.

Improvement of the existing infrastructure facilities, particularly those related to transport sector, is needed for ushering and extending the benefits of basic amenities of health, education and development to the far flung areas. This is at the same time crucial from the perspective of security and safety of the border areas considering the strategic location of the state with respect to the international boundaries it shares with China (Tibet) and Nepal. The issues related to transport sector in Uttarakhand should therefore be accorded high priority at all levels.

Fragile geological disposition, high seismic vulnerability and maintaining the rare and precious biological and ecological diversity are some cardinal issues guiding the developmental initiatives in this state. Frequent occurrence of natural disasters renders maintenance of road connectivity a daunting task for the state machinery. Unprecedented floods during June 2013 severely disrupted road network and forced the planners and

developers to have a serious insight and review of the possible disaster scenario and decide the future course of development inter-alia the construction of roads and highways.

Reading the pulse and realizing the importance of the subject matter an international symposium on “Tackling the Challenges of Slope Stabilisation and Prevention of Landslides in Uttarakhand” was organized by the Uttarakhand Disaster Recovery Project (UDRP), Government of Uttarakhand. The World Bank, JICA and GFDRR co-sponsored this event. The main objective of this symposium was to get the experts from national and international organizations, on one platform, share the existing knowledge and experience, get acquainted with the latest stabilization techniques being practiced in India, South-East Asia and in other parts of the world.

The brain storming sessions following the field visit and discussions after long technical sessions spread across two days were engrossing and the participants were actively and intensively involved. The gist of the proceedings are imbibed in this report and I am sure that the recommendations would go a long way in shaping the future course of action regarding the approach towards road cutting , stabilization and treatment of landslides in hill regions with specific focus to the state of Uttarakhand.

Amit Singh Negi
Secretary/ Program Director
Government of Uttarakhand

1 INTRODUCTION

Uttarakhand is one of the youngest of India's Himalayan states, and thus developmental activities through construction of roads, bridges, and hydropower projects—including tunnels, dams, and underground caverns—are prerequisites for the development of the state.

It also is an abode for four holy shrines: namely, Yamunotri, Gangotri, Kedarnath, and Badrinath. The state has witnessed a rapid expansion in tourism, particularly for religious pilgrimages during the summer in addition to the numerous trekkers who visit the area year-round. A study estimates that about two to three million vehicles traverse along one such pilgrimage route annually, particularly between May and October, referred to as the state's Yātrā (Sanskrit for "journey" or "procession") season (Gupta and Tandon 2015; Sati et al. 2011).

Geologically, the entire area of the state is fragile because it is vulnerable to numerous geohazards. The most common are landslides, earthquakes, and flash floods (including those from landslide lake outburst floods, cloudbursts, and avalanches). Landslides and related mass movement phenomena are common features of these natural hazards that occur annually, posing serious threats to the efforts of developers, planners, and policy makers. It is estimated that there is at least one landslide per year for every 1–2 kilometer stretch of road.

During the past few years, Uttarakhand has witnessed extreme climatic events in the form of low-intensity, incessant, prolonged rainfall as well as short-spell, high-intensity rainfall (also termed cloudbursts). The memory of the June 2013 Kedarnath disaster—also known as the "Himalayan Tsunami," which took the lives of more than 4,000 people—is still fresh in people's minds. During the event, a multiday cloudburst that unleashed a breach of a glacial lake (when the dam containing a glacial lake fails) in the higher regions of Uttarakhand caused debris-loaded flash floods, resulting in toe erosion of hill slopes and erosion of river banks and landslides, blocking all the major road networks. Many stretches of roads in the Mandakini

Construction of hydro power station on the river Alaknanda.
Photo credit: © Dracozlat | Dreamstime.com

Crossing the Ganges, Ram Jhula bridge in Rishikesh, Uttarakhand. Photo credit: © Dheeraj Arora | Dreamstime.com

and Alaknanda river valleys were washed away because of either toe erosion, riverbank erosion, or sliding from the slopes. Human habitations in many localities in these two valleys were either completely washed away or significantly damaged.

In view of the diverse problems due to natural calamities in the area, there is an urgent need for a long-term scientific, holistic, and sustainable program for stabilization of chronic landslides in the state. Therefore, the Government of Uttarakhand–led Uttarakhand Disaster Recovery Project—in association with the Global Facility for Disaster Reduction and Recovery (GFDRR), the Japan International Corporation Agency (JICA), and

the World Bank—organized an international symposium, "*Tackling the Challenge of Slope Stabilization and Landslide Prevention*," held in Dehradun April 27–29, 2015. Various experts from India and abroad attended the symposium, shared their experiences, and informed stakeholders of the available modern techniques used in slope stabilization. (For a list of symposium participants, see appendix A.) Finally, the symposium discussed a best practices road map for landslide studies and corrective measures for the state of Uttarakhand, current issues concerning landslide management, the various research institutions working on different aspects of geohazards in Uttarakhand, and those institutions' available technical know-how.

International Symposium field visit to Kalyasaur.

2 KEY ISSUES PRESENTED DURING THE SYMPOSIUM

After a field visit on April 27, 2015, to the Kalyasaur (also known as Sirobagar) landslide site, the proceedings on April 28–29 comprised five technical sessions in addition to a sixth full session devoted to the Kalyasaur field study. In these sessions, attendees heard about 30 technical presentations by landslide researchers and other experts as well as representatives of private companies involved in slope stabilization. The presentations covered general landslide-related issues, various approaches to risk reduction, different slope stabilization techniques and methods, and successful case studies from both India and abroad.

The following key areas of consensus emerged from the deliberations:

- Landslides are predictable.
- Landslide monitoring, prevention, control, and management are being achieved around the world, and Uttarakhand needs to learn from those experiences and apply them.
- Various types of technologies and innovative approaches to landslide management exist.
- Landslide management should be applied in an integrated, interdisciplinary manner.
- People from local communities, local governments, engineers, natural resource management specialists, geologists, and other stakeholders should all be involved in reducing landslide risk.
- Adopting this integrated approach will not only save costs but also save lives.

The discussions and presentations centered on several primary issue areas: mapping for surface and subsurface investigations, monitoring for early warning systems, slope stabilization methods, and the elements and development of an effective disaster risk management plan. In the discussion summaries below, the presenters' names appear within parentheses after the material they presented.

For more information about each presenter,
see the list of symposium participants in appendix A

2.1 *GENERAL ISSUES INCLUDING MAPPING FOR SURFACE AND SUBSURFACE INVESTIGATIONS*

As noted earlier, most of the landslides in the Himalayan terrain are either rain- or earthquake-triggered and annually cause huge losses of life and infrastructure in the region. Even cross-border occurrences may cause disaster in India. Studies indicate that during recent years, among other extreme climatic conditions, rainfall intensity, particularly during the monsoon season, has increased by more than 50 percent. This has exacerbated the frequency and intensity of landslides and related mass movements, particularly in the state of Uttarakhand (Gupta).

Various organizations in India have conducted landslide studies—including topographical and geological mapping, geotechnical characterization of rocks and soil, and surface and subsurface investigations—and have presented their findings as case studies. Medium- and high-resolution remote sensing data (from differential interferometric synthetic aperture radar [DInSAR] or the Global Positioning System [GPS] and photogrammetry techniques) have also been used for assessing, monitoring, and modeling of landslides (Champati Ray and Reiko Abe). For subsurface investigations of landslides, various geophysical techniques (including ground penetrating radar [GPR]) have been discussed and well documented for various landslide studies in India and abroad (Bhasin).

In summary, the technical know-how exists to identify active and potential landslide zones and to mitigate them using either structural or nonstructural remedial measures. Studies indicated that loss due to landslides is 50–100 times the cost of proper investigation of landslides, and the benefit of reduced loss of life and property is 10 times the cost of appropriate remedial measures (Yudhbir).

2.2 *MONITORING FOR EARLY WARNING SYSTEMS*

There are two kinds of early warning for landslides: one for an individual landslide and another for a group of landslides. The first is shown by the changes in the morphology of landslides, and the second by the climate (mainly rainfall), and these could be used as indicators or precursors for the development of early warning systems (EWS) (Jaiswal).

Because most of the landslides in the Himalayan terrain are rainfall-triggered, temporal forecasting of landslides requires that the rainfall threshold value be set and that a susceptibility map be the means of spatial forecasting. The rainfall threshold depends on the terrain conditions and varies from area to area (Jaiswal and Gupta). It is suggested that the EWS be developed with the participation of the local community, and there should be a village-level EWS. The susceptibility map should therefore be operated by locals.

An individual structure or slope can also be monitored for the surface or subsurface deformation using simple markers or sensors. On-site visualization (OSV) is one such type of sensor and has been extensively used in Japan (Abe) and also in India for the Bangalore Metro project (Abe).

2.3 *SLOPE STABILIZATION METHODS*

Various standard slope stabilization techniques already exist, and these have been successfully applied at various localities in India and abroad (for example, the Watawale landside in Sri Lanka; slopes along roads in Norway, Switzerland, and Taiwan, China; and along Konkan Railways in India). In general, there are two types of protection works: (a) structural or civil works, and (b) bioengineering or vegetative works.

Structural works mainly include different types of nails, anchors, retaining or gabion walls, different slope reinforcement techniques, geocells or geosynthetics, and so on (Adhikari, Gharpure, Ishikawa, Kumar, Mittal, Mukheja, Patni, Studer, Takano). In contrast, bioengineering works mainly include the growth or application of different forms of vegetation on slopes, such as vetiver grass, rambans grass, plated grass lines, grass seeding, turfing, shrub and tree planting, shrub and tree seeding, live check dams, wattling, vegetated stone pitching, jute netting, and mulch mat. These bioengineering structures often perform engineering functions such as catch-type barriers, armor, reinforcements, anchors, support, drains, and so on. The relative strength of the bioengineering or vegetative structure increases with time, whereas that of the civil structure decreases with time (Shrimali). The better approach for any slope stabilization is the combination of civil and bioengineering works (Shrimali).

In functional terms, slope stabilization measures against rockfall can be grouped as follows (Gharpure):

- *Warning measures:* fencing and warning signals
- *Protection measures:* berms or benching, drapery systems, rockfall barriers and embankments, rockfall ditches and trenches, rockfall attenuators of hybrid barriers and hanger nets, debris-flow barriers, rock sheds and tunnels, erosion control mats, and other bioengineering methods
- *Retention measures:* mesh with nails or anchors, surficial strengthening, shotcrete, and chemical stabilization of slope face
- *Prevention measures:* reinforcement of the slope face, rock removal, and drainage systems

Slope stabilization against landslides uses mainly different types of nails, anchors, retaining or gabion walls, different slope reinforcement techniques, geocells or geosynthetics, and so on (Adhikari, Gharpure, Ishikawa, Kumar, Mittal, Mukheja, Patni, Studer, Takano). However, river training works may help in slope stabilization, using various techniques such as geosynthetics: stone-filled polymer rope gabions, geotextile bag-filled gabions; filled geotextile tubes; and sand-filled geotextile bags, containers, or mattresses. Some participants contend that methods to provide proper drainage on the slope may be the best slope stabilization measures.

The selection of mitigation methods should be based on (a) degree of security or reliability, (b) constructibility of the potential option, (c) service life required, (d) suitability regarding the characteristics of the specific rock mass, and (e) cost-effectiveness and the preservation of aesthetics of the area.

2.4 *DISASTER RISK MANAGEMENT PLANS*

Landslide disaster risk management plans must include (a) an understanding of the landslide process, (b) risk assessment and quantification, (c) an assessment of risk acceptability, and (d) a risk reduction strategy (Sandersen). It is strongly advocated that land use management and watershed management should also be part of the disaster risk management plan. The plan should also provide for mitigation and management of destabilized slopes in road planning and construction (Takano, JICA).

Disaster risk management plans should also include dissemination of knowledge and research outcomes to central and state agencies dealing with landslide management plan, and the adverse effects of anthropogenic factors should be stipulated clearly to the engineers, architects, and builders. In addition, the plans should provide for the training of the engineers, administrators, and policy makers engaged in disaster risk management issues. Moreover, communities in the landslide-prone areas should be apprised of the possible risks they are living with (Sandersen and Takano).

highway from Uttarkashi to Rudraprayag. Photo credit © Parin Parmar | Dreamstime.com

3 BEST PRACTICES FOR LANDSLIDE RISK ASSESSMENT

The first and foremost step of any slope stabilization process is to understand and quantify the risk by studying site-specific landslide processes using mapping, modeling, and mitigation approaches. The practices described below for slope stability analysis and landslide prevention should be adopted.

3.1 *PREPARATION OF BASE MAP*

The preparation or selection of the base map is the prerequisite for any landslide-related data collection. This will help to plot all the spatial data necessary for the landslide risk assessment. For studying an individual landslide, the base map should preferably be at 1:1,000 or 1:500 (or even larger) scale, and the contour interval should preferably be 2 meters. These maps may be prepared using data from total stations, drone mapping, laser scanners, light detection and ranging (LIDAR), aerial surveys, or other high-resolution remote sensing methods.

3.2 *DATA COLLECTION I: GEOLOGICAL, GEOMORPHOLOGICAL, HYDROLOGICAL, AND LANDSLIDE INVENTORY*

The base map should plot all the collected spatial data related to

- *Geology,* incorporating lithological structural features (bedding, foliation, joints, faults, fold, shear zones, unconformity, extent of erosion of the various litho-units, and so on) and the interface of soil and rocks;
- *Geomorphology,* including elevated or depressed zones; slope type (convex, concave, or planar); and any break in slope, knickpoints, and so on; and
- *Hydrology,* including the subsurface-like depth of the water table and its seasonal fluctuation.

The spatial extent of the quaternary deposits along with its thickness should also be mapped. To understand the thickness of these deposits, a geophysical survey such as a GPR study or resistivity survey must be undertaken. In addition, land use and land cover (LULC) mapping and the information about the rainfall pattern, including intensity of rainfall in the area, should be known. All the mapping needs to be carried out at a different scale, depending on the area to be covered, but preferably at a scale of 1:500 or 1:1,000. The inventory of all of the active and paleo-landslides in the area should also be known or prepared.

3.3 *DATA COLLECTION II: GEOTECHNICAL*

Geotechnical characteristics of the slope-forming material, including soil and rocks, should be investigated to determine the slope's strength characteristics. This investigation primarily includes index properties, mainly including cohesion and friction angle. As far as possible, the investigators should make efforts to study the undisturbed samples, which will help them to understand the site-specific processes involved in landslides.

3.4 *MODELING AND ANALYSIS OF DATA*

All of the collected data must be analyzed, which involves the correlation of landslide occurrence with various causative factors. To carry out the landslide hazard zonation mapping of the area, the spatial distribution of all the landslides in the area must be correlated with various geoenvironmental factors. This will help to carry out hazard assessment and zonation mapping and would be of immense help to identify hot spots or prioritize zones for disaster risk mitigation.

Finally, modeling of the slope at different stress levels and under various climatic conditions must be undertaken to understand the behaviors of the slope in future using various modeling techniques and software. The modeling will also help in understanding the stress accumulation zones or in ranking the different hazards within the landslide zone, which is also required for the design of proper disaster risk mitigation measures.

3.5 *LANDSLIDE HAZARD MITIGATION*

Finally, after (a) understanding the real causes of the landslides, and (b) modeling the slopes to understand the stressed zones, landslide risk mitigation measures should be planned and designed accordingly. These measures vary from area to area, depending on various factors such as the site's importance, acceptable risk, desired stability (factor of safety), cost-effectiveness, and aesthetic value. Treatment should be holistic, covering the entire mountainside (upslope and downslope of the landslide site), not just the landslide-affected area.

There may be more than one method for slope stabilization or landslide risk reduction, and all options must be considered—including construction of tunnels and bridges or new-road alignment, not just cutting the same slope. This must be done in consultation with technical personnel, policy makers, and community stakeholders.

Normally, the design and tentative costs of the mitigation measures should be prepared by the Uttarakhand Public Works Department (PWD), finalized in consultations with subject experts from public or private sector, and subsequently vetted.

3.6 *SLOPE MONITORING AFTER CORRECTIVE MEASURES*

To understand the efficacy of the corrective measures, the slope must be monitored after the corrective measures are carried out. This monitoring could be carried out by simple traditional methods such as by using nails or other markers, not necessarily with sophisticated instruments. The monitoring may be conducted weekly or monthly, depending on the rate of movement, if any.

4 VARIOUS LANDSLIDE MANAGEMENT ISSUES: EXPERIENCE FROM UTTARAKHAND

There are numerous studies on landslide hazard-related issues in the Himalaya, but the main issues for their management are the following:

- *Scale at which the data are collected.* To study an individual landslide for its corrective measures, data should be collected at a scale of 1:500 or 1:1,000.
- *Coordination among different institutions.* A coordination mechanism for the many organizations and stakeholders working on different aspects of landslide hazards and risk assessment in the state is essential to ensure a holistic and effective approach to risk mitigation.
- *Rainfall data.* Rainfall is the most important triggering factor for the initiation of landslide. Appropriate systems to record and communicate high-resolution rainfall data should be in place, with priority given to high-risk slopes.
- *Holistic approach to landslide treatment.* The treatment of landslides has to be done in a holistic way, covering the entire mountainside slope and landscape and taking into account scientific inputs.
- *Consultation with all stakeholders.* All of the stakeholders involved, including the local community, have to be consulted to ensure that all risks and needs have been considered.
- *Standard operating procedures.* A manual for slope treatment through either structural works or bioengineering works should be developed. Two examples are “European Guidelines for Soil and Water Bioengineering” [EFIB 2015] and “Swiss Norms Bioengineering” [VSS 2008].)
- *Schedule of rates.* A schedule of rates (SoR) for new technologies available for landslide mitigation should be developed. Cost and benefit analysis as well as the level of risk being mitigated are important considerations for decision making.

There are many active and chronic landslides affecting the national and state highways in the state of Uttarakhand. India’s Border Roads Organisation (BRO) and the Uttarakhand PWD are responsible for keeping these highways free from landslides. The current strategy adopted by these organizations is to move from being reactive (debris clearance, in-hill slope cutting, and so on) to being proactive (stabilizing a slope immediately after the roadcut as in the case of Zirakpur–Parwanoo highway).

Floods along the India-Nepal border. Photo credit NASA

5 CURRENT INSTITUTIONAL STRUCTURES IN UTTARAKHAND

The state of Uttarakhand has many central and state government-funded research and educational institutions that deal with various aspects of geohazards such as assessment and evaluation or landslide risk management strategy. The following institutions have vast experience over many years in working on different aspects of slope stabilization, risk assessment, and management of landslides:

- *Wadia Institute of Himalayan Geology, Dehradun.* This research institution has experience in dealing with the geological, geomorphological, and geotechnical aspects of landslides.
- *Geological Survey of India, Dehradun (regional office).* GSI's mandate is to carry out geological mapping. With a large number of geologists, it can undertake mapping on a large scale.
- *Indian Institute of Technology, Roorkee.* This educational institution's departments include earth sciences, earthquake engineering, and disaster management. The services of a large number of students and faculty could be used for hazard and risk-related data collection.
- *Indian Institute of Remote Sensing, Dehradun.* IIRS has the capability to gather and analyze high-resolution satellite data that may be used for landslide mapping and monitoring.
- *Survey of India, Dehradun.* SOI's mandate is to prepare topographic maps of the entire nation at different scales. Its services may be used for the preparation of area base maps.
- *Indira Gandhi National Forest Research Institute, Dehradun.* This premier research institute's mandate is to conduct research related to various forest-related activities. Its experts are available for consultation or design of bioengineering techniques for slope stabilization.
- *Central Building Research Institute, Roorkee.* CBRI's mandate is to generate, cultivate, and promote building science and technology. It assists with the design and building of disaster-resistant structures, including huts.
- *ICAR–Indian Institute of Soil and Water Conservation, Dehradun.* This research institute, under the Ministry of Agriculture, carries out research for the management of land degradation in primary production systems and rehabilitation of degraded lands in different agroecological regions.
- *Disaster Mitigation & Management Centre, Dehradun.* The DMMC (an autonomous center under government of Uttarakhand's Department of Disaster Management) deals with mitigation and management of all

disasters in the state of Uttarakhand. Therefore, it should be the nodal agency for all data collection in the state.

- *Geology and Mining Unit.* This unit of the government of Uttarakhand is responsible for mapping geological reserves, assessing hazards, and monitoring mining activities. The data it collects may be utilized for hazard and risk managemen.
- *Border Roads Organisation, New Delhi:* The BRO, which develops and maintains road networks in India's border areas, is mainly responsible for the construction and upkeep of roads and bridges in the interior parts of the Himalaya.
- *Uttarakhand Public Works Department, Dehradun:* The PWD's mandate is to build, cut, and repair the roads (except in the interior parts of the Himalaya) adjoining the villages.

Of the available institutes in the state of Uttarakhand, the government of Uttarakhand's agencies are the PWD, the DMMC, the Irrigation Department, the Forest Department, the Revenue Department, and the Geology and Mining Unit.

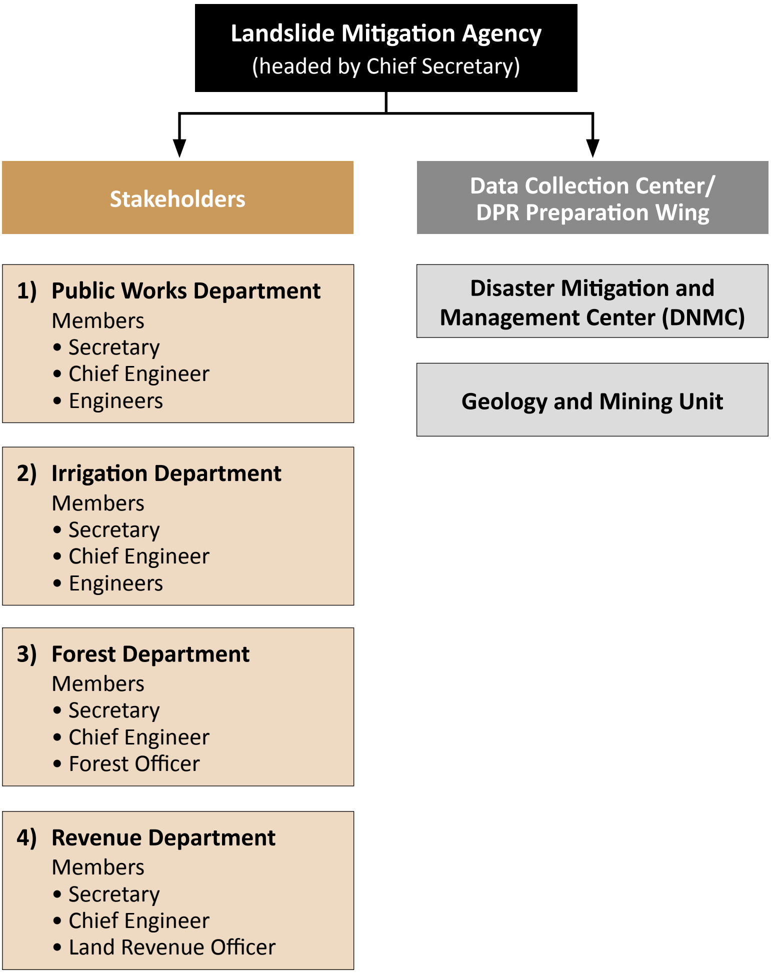
Mechanism should be developed to synergize the activities of the organizations listed above, particularly related to hazards, to gain the maximum benefits.

6 A RISK MANAGEMENT STRATEGY TO REDUCE LANDSLIDE HAZARDS: THE WAY FORWARD

The following suggestions were discussed by the workshop participants as options to reduce landslide risk in Uttarakhand:

- *Designation or establishment of a nodal agency or core group.* The agency or group should comprise some technical personnel as well as representatives of various stakeholders' departments (such as the PWD, Forest Department, Irrigation Department, Revenue Department, DMMC, and Geology and Mining Unit), in line with Japan's International Sabo Network. This nodal agency or core group should be headed by a senior officer, possibly a chief secretary. Once this is established, all stakeholders' departments would work under the ambit of the core group or nodal agency, which could be named the Landslide Mitigation Agency (figure 1). It will assist all the stakeholders' departments to

Figure 1. Structure of Proposed Landslide Mitigation Agency



Note: DPR = detailed project report.

interact and coordinate freely and to plan and design stabilization measures, not only for individual landslides but also for the stability of entire slopes in a holistic manner. the nodal agency must have separate centers to perform the following tasks:

- *Hazard and risk assessment:* This task may be carried out by the DMMC and Geology and Mining Unit, in collaboration with various research Institutes.
- *Slope stabilization control measures and related design:* This task may also be carried out by the DMMC and Geology and Mining Unit, in collaboration with various research institutes, and the tentative cost for the design could be prepared by the Uttarakhand PWD.
- *Implementation of stabilization measures:* This task could be outsourced to private agencies.

- *Interaction of competent technical personnel in the nodal agency with research organizations to collect data and communicate findings*. The nodal agency's technical personal would keep the agency apprised of any new technology or findings by the research organizations. This will also help to have all the required data for slope stabilization on one platform (that is, with the nodal agency).

- *Development of a slope stability plan.* On the basis of an assessment of solutions for the stabilization of a landslide or slope, the nodal agency, after deliberation with members and stakeholders, should devise a plan for slope stability.

- *Installation of rain gauges.* To develop a disaster management plan and the EWS, a rain gauge must be installed in each village. These rain gauges should possibly be operated by the gram pradhan (village head).

- *Preparation of guidelines or manual for civil and bioengineering works.* The work toward the preparation of the guidelines or manual for the civil works or by bioengineering works (for example, the "European Guidelines for Soil and Water Bioengineering" [EFIB 2015] and "Swiss Norms Bioengineering" [VSS 2008]) must be initiated, possibly with the help of research organizations and Indian Institutes of Technology working in the related field.

- *Initiation of SoR finalization.* The nodal agency may initiate the process toward finalization of the schedule of rates (SoR) for new technology available in landslide mitigation; at times, nonavailability of the SoRs may be the deterrent factor for the use of the technology.

- *Assistance with land use and development procedures and regulations.* The nodal agency should also work toward the preparation of the standard operating procedures for future land use planning and regulations for further development, including the regulations for any slope interference. This work should integrate technical, academic, and administrative approaches.

- *Documentation of case studies.* All of the case studies must be documented properly, addressing all of the issues and challenges faced.

- *Public dissemination of hazard-related information.* The nodal agency should ensure that knowledge is disseminated to local residents and tourists about the possible hazards in the area. Public awareness could reduce loss and casualties and save on the ultimate cost.

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REFERENCES

EFIB (European Federation for Soil Bioengineering). 2015. “European Guidelines for Soil and Water Bioengineering.” Reference work (in German, English, Spanish, Portuguese, Italian, and French), EFIB, Aachen, Germany.

Gupta, V., and R. S. Tandon. 2015. “Kinematic Rockfall Hazard Assessment along a Transportation Corridor in the Upper Alaknanda Valley, Garhwal Himalaya, India.” *Bulletin of Engineering Geology and the Environment* 74 (2): 315–326.

Sati, S. P., Y. P. Sundriyal, N. Rana, and S. Dangwal. 2011. “Recent Landslides in Uttarakhand: Nature’s Fury or Human Folly.” *Current Science* 100 (11): 1617–20.

VSS. 2008. “Swiss Norms Bioengineering.” Reference work (in German, English, Italian and French) SN 640 680, Swiss Association of Road and Transportation Experts (VSS), Zurich.