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Landslide Hazard Mitigation
in the Hindu Kush-Himalayas

Editors
Li Tianchi
Suresh Raj Chalise
Bishal Nath Upreti

about the ICIMOD

The International Centre for Integrated Mountain Development (ICIMOD)is an international organisation devoted to development of the Hindu Kush-Himalayan region covering all or parts of eight sovereign states, Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. The Centre is located in Kathmandu, Nepal. The primary objective of the Centre is to promote the development of an economically and environmentally sound mountain ecosystem and to improve the living standards of mountain populations.

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Cover Plate
Landslide on the left bank of the Sunkoshi, Nepal (Li Tianchi)
Landslide control and measures on the roadside at Sindhuli-Bardibas, Nepal (Li Tianchi)
Debris flow in Dongchuan, Yunnan, China (Li Tianchi)

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Preface

The Hindu Kush-Himalayan (HKH) Region is the most dominating physiographic feature on our planet. Constituting the youngest mountain system in the world and with unstable geologic conditions, the terrain is fragile, giving rise to unstable slope-land systems. Characterised by a monsoon climate, the region commonly experiences extreme weather events and intense seasonal precipitation which commonly trigger natural hazards such as debris flows and landslides. The peoples of the HKH region suffer greatly from these disasters. Every year, landslides and related hazards cause several billion US$ in economic losses and thousands of deaths are suffered in the region, accounting for about 50 per cent of the total deaths from such hazards in the world. Apart from natural conditions, large-scale deforestation, unplanned human settlement, extension of agriculture on to landslide prone areas, and badly-engineered mountain roads have rapidly increased the number of landslides in the HKH. As the population of this region increases, the frequency and intensity of landslides is also bound to increase. Institutional capacity to deal with these problems on a systematic basis needs to be strengthened substantially in the regional countries through generation of awareness and dissemination of appropriate technology and skills.

In the last few decades, studies and management of landslides have significantly increased in scope. Dissemination of this knowledge can help mitigate landslide hazards in the region. The knowledge needs to be disseminated both to the grass roots as well as to higher technical levels. A multidisciplinary approach and bringing together of professionals of different disciplines such as engineering geologists, geotechnical engineers, hydrologists, meteorologists, geomorphologists, foresters, agricultural scientists, and civil engineers are the keys to effective mitigation of landslide hazards.

Landslide studies and management requires input from professionals from diverse fields as well as very close interaction among them. Publications dealing with the problems of landslides by pooling together diverse subjects, such as geology, engineering geology, geophysics, geotechnical engineering, civil engineering, hydrology, meteorology, and bioengineering, in one volume are not common, and they are particularly rare for use on the HKH region. The present publication is an attempt to fill this gap.

The resource materials contained presented in this volume are from China, India, Japan, Nepal, and the UK. All the papers that appear in the volume were reviewed and edited before the publication. The first part of the volume has 14 papers that deal with the principles and investigation of landslides and debris flows and the second part has 4 papers dealing with mitigation and management based on case studies in Nepal and China. An attempt has been made to include related topics such as the physical aspects of the HKH region (geology, physiography, seismicity, climate, and rainfall) and their bearing on landslide problems and techniques of investigation and mitigation methods. While preparing this volume care has been taken to keep the articles as simple as possible and understandable by a diverse group of professionals.

These days specialists as disparate as foresters, civil engineers, development workers, tourist guides, and agricultural advisors may be confronted directly or indirectly with landslide risk assessment and hazard mitigation. However, few have any formal training in the subject, and there are few resource books that can be used by the technically able non-specialist, and even less that are specifically concerned with the HKH region. This book, which is the final product of materials prepared for a series of regional training programmes organised by ICIMOD, is designed to fill this gap. It is a comprehensive reference manual, with information about a wide range of topics related to landslide development and mitigation and assessment of risk. It is hoped that the chapters will provide useful reference material both for field engineers and for the many other experts engaged at the field level in landslide hazard management and control in the HKH countries. It can also be used as course material for academic and professional training on landslide management and control as well as for students of civil engineering and the geosciences.

The first draft of the resource materials for training in landslide hazard management and control was tested during a 4-week pilot training course from May/June, 1996, in collaboration with the Water Induced Disaster Prevention Technical Centre (DPTC) of the Ministry of Water Resources, His Majesty's Government of Nepal. Altogether 18 professionals, mainly engineers and geologists from Bangladesh, China, India, Nepal, and Pakistan, participated in this pilot course. Subsequently the training materials were sent to experts for review, and then a revised version was received from the respective authors based on the comments and suggestions from the reviewers. The revised training materials were tested again during the second training course conducted by ICIMOD during September/October, 1999, which was attended by 16 participants from Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. Fourteen trainers and resource persons from Austria, China, Germany, India, and Nepal provided the training. In order to improve the capacities of the relevant partner institutions in the countries of the Hindu Kush-Himalayan region in training and applied research for disaster mitigation, with particular reference to landslide hazards, some training materials were selected for publication in this volume.

It is hoped that the materials in this volume are useful to experts as well as middle-level technical manpower in the related fields. The materials might also be useful for academic institutions for courses in civil engineering, geotechnical engineering, engineering geology, geomorphology and other related subjects with particular reference to the HKH.

Foreword

One of the goals set by ICIMOD in its Mountain Natural Resources' Programme is "to improve the conditions of mountain resources and environments in the Hindu Kush-Himalayan (HKH) region by reducing and eventually reversing their degradation." The programme activities include the identification of measures to mitigate different types of natural hazards which result in the loss of natural resources; promotion of skills and methodologies for natural hazard assessment; and improvement of public awareness for better disaster preparedness in mountain areas.

ICIMOD has developed and implemented different activities in landslide hazard management and control since 1994 with financial support from the Government of Japan. These have included training and capacity building, research, documentation, and information sharing — with a major focus on training people involved at different levels in the field of landslide hazard mitigation and management. The common theme in all these activities is improved landslide hazard management based on a better understanding of the different natural and manmade processes and, through this, improved planning of infrastructure, settlements, and sloping agricultural land management. With the increase in construction and development activities on sloping lands across the HKH region, it has become essential to have a better understanding of geo-environmental, hydro-climatic, biophysical, bioengineering, and socio-institutional processes in order to avoid an increase in disasters.

I would like to express my sincere appreciation and thanks to the Government of Japan and the United Nations Development Programme (UNDP) for their generous support to ICIMOD's Landslide Hazard Management Programme and hazard mapping and risk assessment activities (2000-2002), which are part of the Participatory Disaster Management Programme (NEP/99/014) implemented by UNDP/Nepal. Professor S. R. Chalise and Professor Li Tianchi from ICIMOD were the coordinators of the programme at various phases. Professor B. N. Upreti of the Department of Geology,Tribhuvan University, and Mr. M.N. Sharma, TAEC Consult (P) Ltd., assisted with the technical editing. Many thanks are also due to the experts and resource persons who shared their knowledge and experience during the training events and also spent valuable time preparing and revising the training materials.

ICIMOD would welcome any comments and suggestions that will help us prepare an improved future edition of the publication.

Binayak Bhadra
Director of Programmes
ICIMOD

Acknowledgements

These resource materials are the outcome of the contributions of many people. The editors are thankful to all the authors for contributing their papers to this publication and for their unfailing cooperation and support. As most of the papers were originally in a different format and were not intended for formal publication, the authors had to do a great deal of rewriting. This and other necessary work consumed a lot of time and, therefore, preparation of this document took longer than planned.

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This publication would not have been possible without the support of all the staff from ICIMOD, in particular, we would like to record our appreciation and thanks to the former Director General of ICIMOD, Mr. Egbert Pelinck, for his encouragement and untiring support for the landslide hazard management programme and for the publication of this document. We are equally thankful to the present Director General, Dr. J. Gabriel Campbell, and Dr. Binayak Bhadra, Director of Programmes, ICIMOD, for their keen interest and support for this publication. Special thanks are due to Ms. Greta Rana, Senior Editor, and Dr. A. Beatrice Murray Shrestha, Editor, of ICOD, ICIMOD, for all their work in bringing the document and its contents into its current shape. Ms. Reeta Rana, Senior Secretary, Mountain Natural Resources Division, deserves special thanks for her secretarial support Thanks are also due to Dr. S.M. Rai for computer drafting most of the figures included in this volume and to Mr. Asha Kaji Thaku and Mr. Sushil Man Joshi for the long hours spent on the graphics and layout.

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Acronyms and Abbreviations

BIS	Bureau of Indian Standards
BP	bank protection
BT	Basement Thrust
CD	Check Dam
CDP	common depth point (technique)
CMP	common midpoint (technique)
cumec	cubic metres per sec (stream/river discharge)
DCPT	Dynamic Cone Penetration Test
DEM	Discrete Element Method
DPTC	(Water-induced) Disaster Prevention Technical Centre
DoR	Department of Roads
EDM	Electronic Distance Meters
EP	Electrical Profiling
ERT	Electrical Resistivity Tomography
FOS	Factor of Safety
GLOF	Glacial Lake Outburst Flood
GPR	ground penetrating radar
GRM	Generalised Reciprocal Method
ITT	Indus-Tsangpo Thrust
ITS	Indus-Tsangpo Suture Zone
HDP	high damage potential
HFT	Himalayan Frontal Thrust
HH	high hazard
HHZ	High Himalayan Zone
HMGN	His Majesty's Government of Nepal
HP	hazard probability
HR	high risk
IDA	International Development Agency
IMHE	Institute of Mountain Hazards and Environment
JICA	Japanese International Cooperation Agency

LDP	low damage potential
LH	low hazard
LHEF	Landslide Hazard Evaluation Factor
LHM	landslide hazard management
LRA	landslide risk assessment
LR	low risk
LZE	Lesser Himalayan Zone
M	Magnitude (of earthquake)
masl	metres above sea level
MB	Mahabharat Thrust
MBT	Main Boundary Thrust
MCT	Main Central Thrust
MDP	Moderate Damage Potential
MFT	Main Frontal Thrust
MHT	Main Himalayan Thrust
MH	moderate hazard
MM	Modified Mercalli Scale
MR	moderate risk
MRE	Mountain Risk Engineering
NEA	Nepal Electricity Authority
OCR	Over Consolidate Ratio
RA	risk assessment
RAM	Risk Assessment Matrix
RFRP	Road Flood Rehabilitation Project
RMR	rock mass rating
RQD	rock quality designation
SDC	Swiss Development Co-operation
SMR	slope mass rating
SN	State-of-Nature
SPT	Standard Penetration Test
SRC	soil, rock, and concrete
SSI	Sub Surface Imaging
STD	South Tibetan Detachment
TEHD	Total Estimated Hazard
THZ	Tethys Himalayan Zone
TRZ	Trans Himalayan Zone
VES	vertical electrical sounding
VHDP	very high damage potential
VHR	very high risk
VLDP	very low damage potential
VLR	very low risk
WERDP	Water and Energy Resources Development Project

Glossary

adit	nearly horizontal tunnel used for exploration; excavation of a main tunnel; or access, drainage, or ventilation of a mine or other structure
base-flow	flow in a river from groundwater sources rather than from precipitation events
bedload	the amount of solid material (like sand, gravel, and boulders) carried along a river-bed by rolling pushing or bouncing (in contrast to the sediment load which is carried in suspension); the material can result from landslides, debris flows, and GLOFs as well as coming from the river-bed
berm	a horizontal ledge cut between the foot and top of an embankment (or other slope) to stabilise the slope by intercepting sliding earth
break of slope	an abrupt change of slope resulting from differences in erosional history of the terrain or from lithological contrasts; the change of slope in the long-profile of a river bed is termed a knickpoint (nickpoint) or rejuvenation head
catchment area	in British usage, the total area drained by a single stream or river with all its tributaries; in the USA, the intake area and all areas that contribute surface water to the intake area of an aquifer (see also river basin, watershed)
cumec	a measurement unit relating to the rate of discharge of a stream; refers to the volume of water passing through a particular section of the stream and is obtained by multiplying the cross-section of the channel at the position of the measuring station by the velocity of the flow
damage potential	a measure of the damage that could be caused by a disaster like a landslide in the form of loss or damage to life and property
debris	a superficial collection of broken rocks, earth, and other inorganic material (usually that has been removed from an original site by streams of water or ice and redeposited)
debris avalanche	a very to extremely rapid debris flow

debris flow	a rapid mass movement of loose soil, rocks, and organic material along with entrapped air and water to form a slurry that flows downslope
debris slide	a slide of coarse-grained soil usually containing angular rock fragments, typically made up of debris from glaciers or from colluvium resulting from the disintegration of rocks in situ
decollement	deformation of superficial rocks or sedimentary beds by folding or faulting without the rocks at depth being affected; usually accomplished by sliding over the underlying rock
dip direction	the direction of a discontinuity perpendicular to the strike of the rock strata given in terms of the points of the compass
dip	the maximum inclination of a structural discontinuity to the horizontal plane measured in a direction perpendicular to the strike of the rock strata
dislocation	the displacement of rocks on opposite sides of a fault; area of a fault along which a slip has occurred
earth flow	a flow with a characteristic bowl-like depression at the head where the slope material becomes liquefied and flows out; the flow is usually channelised on the slope and spreads out at the toe; such flows generally occur in fine-grained materials or clayey rocks under saturated conditions
electrical resistivity	the electrical resistance that a unit volume of a particular material offers to the flow of current at 0°C; it is the reciprocal of conductivity and is measured in ohm metres
epicentre	point on the earth's surface that is directly above the focus of an earthquake
factor of safety (F)	for a rock slope, the ratio of the total force resisting sliding to the total force tending to induce sliding
falls	an abrupt movement of materials that become detached from steep slopes or cliffs and drop down by free fall or a series of leaps and bounds
fault	a rupture or fracture of rock strata due to strain, in which displacement is observable
fault plane solution	the results of calculations of the type or nature of movement of an earthquake
fault zone	(fracture zone) an area in the vicinity of the fault where the rocks are normally highly crushed or sheared
first motion data	direction of motion of earliest seismic wave from an earthquake
flash flood	a short-lived but rapid rise of water in a river due to heavy rainfall or the collapse of a dam (natural or artificial)
flashy river	a river often subject to flash floods
flat	low lying, or lacks any curvature

focal mechanism	the direction of slip in an earthquake and the orientation of the fault on which it occurs, represented by a 'beach-ball' diagram
focus	the point source of an earthquake
geomorphological hazard	a perceived event, natural or human-induced, which causes a fluctuation or malfunction in the normal operation of a geomorphological process sufficient to pose a threat to life and property. Realisation of the hazard usually leads to an extreme event (e.g., avalanche, earth-flow, landslide, flood) which may or may not culminate in disaster
geomorphological map	a map depicting selected terrain features which assists in understanding the evolutionary history of the landforms of an area
geomorphological processes	the physical and chemical interactions between the earth's surface and the natural forces acting upon it to produce landforms (gravity, ice, rivers, waves, wind and so on)
geomorphological unit	part of a landform, like a mountain range or plateau on a large scale, or slope or stream bed on a small scale
geomorphology	the scientific study of the origin of landforms based on a cause-and-effect relationship, especially the genesis, evolution, and processes involved in the formation of the surface forms of the earth
geophone	a receiver or detector for seismic waves that converts ground motion into electrical energy, the output of a geophone is further filtered, amplified, and recorded on a seismograph. The record of each geophone is called a trace and a group of traces makes a seismogram (i.e., the record produced by a seismograph).
glacial lake outburst flood (GLOF)	a debris torrent resulting from the sudden and catastrophic release of water from a lake of glacial origin; such lakes are usually impounded by glacial ice or a moraine
hazard	the probability that a particular danger occurs in a particular area within a given period of time
highland-lowland interactions	the impact of upland activities and events on lowland areas
inclination	see 'dip'
insolation	quantity of solar radiation per unit area falling on a surface
island arc	a lengthy chain of oceanic islands which frequently exhibit an ocean trench on the convex side; many are volcanic and generally the location of severe seismic activity
landslide hazard	a measure of the probability of a landslide occurring at a particular location within a particular time
landslide hazard zonation	a macro approach that categorises an area into various zones from very stable to very unstable based on the hazard associated with separate slope facets

landslide risk	refers to the probable extent of damage if a landslide occurs and is a function of the hazard probability and the damage potential
landslide	commonly used to denote the downward and outward movements of slope-forming materials along surfaces of separation by falling, sliding, or flowing at a faster rate, a type of mass wasting; sometimes used specifically to refer to 'slides' (see below)
landslide-dam	a natural river dam formed by the rock, earth, debris, and or mud transported by a landslide; easily formed in the steep, narrow valleys of high rugged mountains, and can fail catastrophically, causing major downstream flooding and loss of life
lithology	the study of rock characteristics (e.g., particle size, physical and chemical character) and rock types
macrobasin	a complete river basin or a large part thereof
mass wasting	the general term for a variety of processes by which large masses of earth materials are moved under gravity, either slowly or quickly, from one place to another (see 'mass movement')
mass movement	(gravitational mass movement) the downhill movement of surface materials under the influence of gravity but assisted by buoyancy due to rainfall or snow melt, see also landslide
microbasin	the area drained by a stream or small river
microtopography	surface features with dimensions from a few centimetres to one metre (see topography)
mid-oceanic ridge	a large scale linear elevation rising from the ocean floor approximately in the middle of the N and S Atlantic and the Indian Oceans; it marks the boundary of adjoining plate margins
Modified Mercalli Scale	a subjective measure that describes the intensity of an earthquake shock felt at a particular place
Moho	(Mohorovicic discontinuity) boundary surface or sharp seismic discontinuity that separates the earth's crust from the subadjacent mantle
mud flow	a type of earth flow containing about 50% of sand, silt, and clay-sized particles that are well saturated and flow rapidly
mud slide	a landslide of essentially homogeneous clay-silt material, but with a lower water content and without the velocity or linear extent of a mud flow
nickpoint	see 'break of slope'
nodal plane	fault plane along which rupture takes place
normal fault	a dipping fault plane with the top dropping down; this arises from extension when two blocks of rock diverge
ocean trench	(ocean deep or foredeep) a deep trench (>5,500m) of the ocean floor, often associated with the subduction zone at the margins of two tectonic plates

orogenic belt	a linear region that has undergone folding or other deformation during an orogenic (geotectonic) cycle
orography	the study of mountain systems and depiction (mapping) of their relief; the terrestrial relief form of mountains
penstock	the water conduit from the intake to the turbines in a hydroelectric plant
piping	the presence of sloping tube-like features in rock, often marked by seepage
precipitation threshold	the level of precipitation (rainfall duration and intensity) needed to initiate a landslide, debris flow, or similar event; the threshold is specific for a particular slope and hazard as it depends on a large number of factors like slope angle, soil type, vegetation cover, and soil saturation, not just on rainfall, however, generalisations can be made for different types of slope in different areas
ramp	steep inclined segment of a thrust fault or steep inclined plane
rheology	the branch of physics concerned with the flow and change of shape of matter
Richter Scale	a logarithmic scale used to express the magnitude of an earthquake
risk	the probability that a potential hazard will be realised and the probability of the harm itself; risk is the combined effect of the probability of occurrence of an undesirable event and the magnitude of the event
river basin	(drainage basin) the area drained by a river and all its tributaries, usually large-scale (see watershed, catchment area)
rock material/rock matrix	the intact material in rock between discontinuities, for example, a hard piece of rock taken from a drill core
rock or rock mass,	the total in situ medium of rock including all discontinuities like joints, fractures, faults, etc
rupture zone	overall geological area affected by an earthquake where the stresses produced exceeded the ultimate strength of the rocks, as shown by crushing and fracturing
sediment load	the amount of material carried down by a river in suspension, solution or as bed load
seismic activity	earthquake activity
seismograph	instrument for detecting and recording earthquakes
seismogram	the record produced by a seismograph illustrating the magnitude, frequency, and duration of seismic waves
shotcreting	a process of conveying mortar or concrete through a hose at high velocity on to a surface, the material bonds tenaciously to a properly prepared concrete surface and to a number of other materials

slickenside	a polished and scratched planar surface at a fault plane produced by friction between the opposing sides of a fault, the surface only feels smooth when rubbed in the same direction as the former movement
slides	(sometimes 'landslide') mass movements with a distinct surface of rupture separating the slide material from more stable underlying material (slope failure); the downward sliding material is usually relatively dry.
slope facet	a part of a hill slope that has more or less homogeneous characteristics showing consistent slope direction and inclination; facets are mostly bounded by ridges, spurs, gullies, or rivers; local within a facet may be called sub-facets.
slope morphometry	the features of a slope including shape, angle, and aspect
strike slip fault	a fault in which the movement is parallel to the fault strike, there is no vertical motion (see also transform fault)
strike	the angular direction with respect to north (compass bearing) of the line of intersection of a bedding plane, fault plane (then called fault strike), or other planar structural feature (e.g., discontinuity plane) with a horizontal plane
subduction zone	the linear areas that represent the zones where crustal plates are overridden by other plates and are forced down into the underlying mantle along an oblique plane of thrusting; they mark plate collision zones
teleseismic phase data	data from a distant earthquake
thrust fault	a dipping fault plane with the top riding over the bottom; arises from compression, when two blocks of rocks converge (also known as a reverse fault)
topography	the surface features of the earth's surface including the relief, the terrain, and all the features in the landscape created by human endeavour; i.e., the shape and form of the earth's surface
transcurrent fault	a type of strike-slip fault
transform fault	a special type of strike-slip fault forming the boundary between two moving plates, usually along an offset segment of the oceanic ridge
water balance	in hydrology used to mean the input/output/storage relationship of water in a given area (includes calculations of precipitation, overland flow, throughflow, evapotranspiration, storage and others)
watershed	formerly used to mean a divide, the water-heading from which headstreams flow to different rivers; now generally used to mean the area drained by a particular river or stream with all its tributaries (the catchment area of a single drainage basin) — most commonly a smallish river. Although river (drainage) basin and watershed are more or less synonymous, river basin is usually used for the large scale (regional), watershed for the small scale (local)

About the Authors

T.L. Adhikari is a Technical Director of ITECO Nepal (P) Ltd, a Swiss-Nepal joint venture engineering consulting company based in Kathmandu, Nepal. He received his first degree in civil engineering from the University of Roorkee, India in 1984 and a Masters in Soil Engineering from the Asian Institute of Technology, Thailand in 1998. Most of his professional career has been devoted to the solution of geotechnical problems in landslides and gully erosions related to highways and hydropower facilities in the mountainous regions of Nepal and Bhutan. He was the responsible civil cum geotechnical engineer in the design and construction of the Salleri-Chalsa small hydropower (1984-87), Charnawati rehabilitation (1988-90), Arniko Highway rehabilitation (1992-93), Thankot-Naubise rehabilitation (1991), and Bhainse river training (1994) projects in Nepal and the Road Bank Stabilization project in Bhutan (1993). He is also involved in the training of engineers and geologists in landslide management work in Nepal and Bhutan.

R. Anbalagan is an Assistant Professor of Engineering Geology at the University of Roorkee, India. After serving for 11 years in the Geological Survey of India, he joined Roorkee University in 1988. He has contributed to the field of Landslide Hazard Zonation and Landslide Risk Assessment mapping. Dr. Anbagalan has aobut 45 research papers to his credit published in international and national journals and conferences. He has supervised 4 PhD theses in engineering geology. In addition, Dr. Anbalagan has supervised 30 M.tech. and 7 M.E. dissertations. He has also contributed chapters to the Mountain Risk Engineering Handbook published by ICIMOD and edited a book on "Design Practices in Enrthquake Geotechnical Engineering. He has been a Professor in the University of Asmara, Eritrea, since 1999.

R.K. Bhandari has a PhD in Soil Mechanics from the Imperial College of Science & Technology, University of London. After serving the Central Building Research Institute of India until 1989 as its Director, from 1990-1995 he was chief of a major programme on Landslide Hazard Mapping in Sri Lanka for the United Nations Centre for Human Settlements (Habitat). He is currently the Head of the International Science & Technology Affairs Directorate of the Council of Scientific & Industrial Research of India.

The main professional contributions of Dr. Bhandari lie in the areas of natural disaster reduction; multi hazard mapping; geo-technical instrumentation of landslides and other mass movements and early warning; hazard, risk, and environmental impact assessment; and sustainable development of hilly areas in hazardous zones. He was the first to enunciate undrained loading as a fundamental mechanism for occurrence of low angled mudslides, jointly with Professor J N Hutchinson of Imperial College, London.

D. Bhattarai is a Senior Divisional Engineer at the Department of Water Induced Disaster Prevention (DWIDP), Ministry of Water Resources, His Majesty's Government of Nepal. He received a BSc. from Tribhuvan University in 1970, a BSc in Civil Engineering degree from Middlesex Polytechnic, U.K., in 1975, and a P.G. Diploma in Sanitary Engineering from IHE, Delft, Netherlands in

1986. He has worked for various government departments spanning a service period of about 24 years. At present, he is involved in training engineers and geologists in the field of water induced disaster prevention.

B.B. Deoja earned an undergraduate degree in civil engineering from the University of Peshawar, Pakistan, in 1967 and a graduate degree from the University of Washington, Seattle, in 1986. He has served in the public sector of Nepal in various capacities: Deputy Director General of Department of Roads, Director General of Civil Aviation, Board Member of the Royal Nepal Airlines Corporation and Joint Secretary in the Ministry of Works and Transport. Currently Mr. Deoja is Joint Secretary in the Ministry of Physical Planning and Works.

Mr. Deoja was involved in design, construction, and maintenance of mountain roads in Nepal from 1967 to 1985. He developed Mountain Risk Engineering (MRE) at ICIMOD from 1988 to 1990 as a Programme Coordinator. He also co-authored the MRE Handbook and authored an ICIMOD occasional paper on Sustainable Management of Mountain Roads and Other Infrastructure in the Hindu Kush-Himalayas.

Mr. Deoja has played an instrumental role in the formulation of policy and acts in the transportation and public infrastructure sector in Nepal since 1992.

J. Howell is a British professional soil scientist who has specialised in the use of vegetation for slope stabilisation (bio-engineering) in South Asian countries, as well as in environmental assessment and other technical fields. He has worked in Nepal periodically for fourteen years, as well as in other parts of the Himalayas, on a series of natural resources and road development projects. He is a director of Living Resources Limited, a UK-based consulting company.

N.R. Khanal is an Associate Professor in the Central Department of Geography, Tribhuvan University, Kathmandu Nepal. His main field of research is mountain geography with a focus on landscape and resource dynamics. He has studied the extreme geohydrological events that recently occurred in Nepal, such as the debris flow at Larcha and landslides and floods caused by extreme precipitation events in the Kulekhani area in 1993, Lele watershed in 1981, and Syangja and Butwal in 1998. Similarly, he has also studied floods and their impacts in the lowland Terai, in Mahuli Khola in the Eastern Terai, and Karnali River in the Western Terai.

Mr. Khanal is also actively involved in organising the training programme on landslide hazard control and management. From its inception, he has been actively involved in the Mountain Risk Engineering Unit of Tribhuvan University, which is involved in organising training and developing a training curriculum in the field of Mountain Risk Engineering. Mr. Khanal has a number of research publications to his credit in national and international journals.

S. Miyajima obtained his degree in Bachelor of Agriculture form the Tokyo University of Agriculture and Technology, Japan, in 1984. He is presently working as Deputy Director of the River Planning Division at Hokkaido Development Bureau, Japan. Mr. Miyajima joined the Hokkaido Development Agency in 1984 and worked in different capacities as the Chief Officer of Sabo Planning, River Planning and Sea Coast Planning, Deputy Director of the River Improvement Division, and Director of Sanru-dam. He also worked as the Deputy Director of River Planning Division of the Ministry of Construction, Government of Japan from 1994 to 1996 and was assigned to work in Nepal as a Sabo expert through the Japan International Cooperation Agency (JICA).

During his assignment in Nepal he worked as a Sabo expert in the Water Induced Disaster Prevention Technical Centre (DPTC), His Majesty's Government of Nepal. Mr. Miyajima is a member of the Japanese Society of Erosion Control Engineering.

S.R. Pant received his MSc with Honours from the Faculty of Geophysics, St. Petersburg State Mining Institute, Russia in 1987 and is now Lecturer in Applied Geophysics in the Department of Geology, Tribhuvan University, Kathmandu, Nepal. His research work has focused on the application of geophysics in engineering and environmental studies, mainly using electrical, electromagnetic, and seismic methods, with current research interests in the field of correlation of electrical resistivity with hydraulic parameters and rock mass quality. Mr. Pant has supervised many MSc students and has worked in a variety of projects to provide geophysical services related to hydropower development, glacier lake study, groundwater exploration, mineral exploration, and road construction and maintenance. He has published many papers related to the application of geophysical methods in landslide studies.

M. Paudel is a civil engineer. He received his civil engineering degree in 1976 from the University of Roorkee, India, and a Master's in Engineering in Geotechnical and Transportation Engineering in 1985 from the Asian Institute of Technology, Bangkok, Thailand.

Mr. Paudel has worked as an engineer for nearly 25 years in various government departments of His Majesty's Government of Nepal and has been with the Department of Irrigation for the last fifteen years. He was the coordinator of the Irrigation Sector Project funded by the Asian Development Bank and Irrigation Line of Credit Project funded by the World Bank. He also worked as a Project Director at the Water Induced Disaster Prevention Technical Centre, a project funded by the Japan International Cooperation Agency (JICA). He was the Project Manager of the Bagmati Irrigation Project funded by Saudi Arabia, one of the biggest irrigation projects in Nepal. Mr. Paudel has presented many papers on disaster management at different international seminars and symposiums.

G.S. Pokharel is a Geological Engineer with the Nepal Electricity Authority, Kathmandu, Nepal, and presently heads its Geotechnical Division. He received his MSc degree in Engineering Geology in 1978 from the Leningrad Mining Institute in the former USSR. He has a wide experience in the field of engineering geological and geotechnical investigations in a number of hydropower projects in Nepal. Mr. Pokharel was involved in the pre-feasibility and pre-design stage investigation of Arun-III Hydro power project, feasibility study of Karnali (Chisapani) hydroelectric project, engineering geological study, supervision and design of cement grouting and foundation works in the Kulekhani hydroelectric project. In addition to these large projects, he was also involved in the geotechnical investigations of a number of small and medium hydropower projects in Nepal. Mr. Pokharel has also worked in many projects related to debris torrent control and landslide stabilization work.

K.K. Purohit obtained his MSc degree in Applied Geology from the University of Delhi in 1977 and PhD from Garhwal University, India, specialising in geochemistry of migmatites. He was a Research Scholar at the University of Delhi (1977-1979) and Wadia Institute of Himalayan Geology, India (1979-1981). Dr. Purohit joined the Wadia Institute in 1981 as a Scientist and continues to work there.

Dr. Purohit has done extensive geological work in the Himachal and Uttaranchal Himalaya, and also investigated the environmental aspects of Doon Valley soils using the multipurpose and multi-element geochemical mapping technique. Encouraged by the success of the technique, he has extended the work now to the upper reaches of the Himalayan belt. Dr. Purohit has published 17 research papers in national and international journals.

A.B. Singh is Professor of Civil Engineering at the Institute of Engineering (IOE), Tribhuvan University, Nepal, which he joined in 1971. He received an MSc from Moscow Automobile Highway Engineering Institute, USSR, in 1969, and a PhD in Rock Mechanics from the University of New South Wales, Australia, in 1980. As well as teaching, he has served on various technical committees such as the Working Committee of the Royal Commission for Higher Education, 1984; Review Committee on the Design of the Approach Road to the Arun-III Hydropower Project in 1990; Committee for the Investigation of the Bagmati River flood, 1993; and the Technical Committee of the Nepal Bureau of Standards. He has published a number of research papers in national and international journals and has been associated with the design and construction of some important road and dam projects in Nepal. Professor Singh was an Associate Member of the Royal Nepal Academy of Science and Technology for two terms and is currently on the Executive Board of the International Commission on Large Dams, Nepal.

B. Singh is a Professor of Civil Engineering at the Civil Engineering Department, University of Roorkee, India. He obtained his PhD degree from the University of Rookee in 1960. Prof. Singh has published 150 research papers, mainly related to rock mechanics and geotechnical engineering, in addition to 80 consultancy reports. He has guided 13 PhD theses and 40 M.E. dissertations. He is the recipient of 8 national awards. Professor Singh is also the Chairman of the Sectional Committee on Rock Mechanics of the Bureau of Indian Standards as well as the Chairman of the Editorial Board of the Commission on the International Society of Rock Mechanics.

V.C. Thakur is former Director of the Wadia Institute of Himalayan Geology, Dehradun, India and currently CSIR Emeritus Scientist at the same Institute. He received an MSc in geology from the Punjab University, India, and PhD and DIC from Imperial College, London. He has done research work in the Scottish Highlands and Swiss Alps, and has worked extensively in the Himalaya for the past 28 years on regional geology, tectonics, and seismotectonics, with the current focus on seismotectonics and earthquake hazard assessment in the Western Himalaya. Dr. Thakur has published over 100 research papers in national and international journals. He was Chairman of the Himalaya Coordinating Committee of the International Lithosphere Programme from 1992 to 1996, and Convener of the Symposium on Himalayan Tectonics in the International Geological Congress (IGC) in 2000, 1996, and 1989. He has served on various editorial boards and is a Founder Editor of the Journal on Geology of the Western Himalaya. Dr. Thakur was awarded the National Mineral Award of the Government of India and is a Fellow of the Indian Academy of Sciences.

K.B. Thapa, has been associated with Tribhuvan University, Kathmandu, Nepal, since 1974, where he is now Professor in the Central Department of Hydrology and Meteorology. He has carried out many field studies in Nepal related to snow hydrology and floods and has been a consultant for various hydrometeorological projects. Professor Thapa has many research papers to his credit on a wide range of topics related to geomorphology, rainfall runoff and flood studies, and snow hydrology.

B. Tiwari is a graduate in civil engineering from Tribhuvan University, Nepal. He has also obtained a Master's degree in Geo and Biosphere Science from Niigata University, Japan, with specialisation in landslide mechanisms. Mr. Tiwari started his career in 1992 as a civil engineer at the Department of Roads, His Majesty's Government of Nepal. Later he was deputed to the Water Induced Disaster Prevention Technical Centre (DPTC) as a landslide engineer and worked there from 1993 to 1997. During his stay in the DPTC, he was responsible for surveying, investigating, monitoring, and planning and implementating countermeasures for landslides in Nepal. Mr. Tiwari was also involved in providing training on 'landslide mitigation' to government officers through various organisations. He was involved in various preliminary investigation works of disaster events in Nepal as a landslide expert.

Mr. Tiwari was the editor of ' Disaster Review', an annual publication of DPTC and various landslide manuals and reports. He has presented many papers on landslide and geo-techniques in national and international seminars and has published research papers on landslides, on aspects like the residual shear strength of soil. Presently Mr. Tiwari is a research fellow at the Research Institute of Hazards, Niigata University, Niigata, Japan.

N.S. Virdi has been associated with the Wadia Institute of Himalayan Geology (WIHG), Dehradun, India since 1977, where he has been Director since February 2000. From 1975 to 1979, he taught at the Punjab University, Chandigarh, and Indian Photointerpretation Institute (now Indian Institute of Remote Sensing), Dehradun, India, and has been Courtesy Professor at the University of Oregon, U.S.A. since 1997. He was awarded a Commonwealth Scholarship to study in Britain and received his PhD from the University of Leeds in 1973. Dr. Virdi has done extensive geological work in the Indian states of Ladakh, Jammu & Kashmir, Himanchal Pradesh, and Uttaranchal. His work on geological hazards and their management has included geotechnical feasibility surveys for hydel projects, ropeways, tubewells, and building complexes, and control of landslides. In 1985, Dr Virdi was awarded the National Mineral Award by the Ministry of Steel and Mines, Government of India, for outstanding contributions to the fundamental aspects of earth sciences and in 1996 an MSc by Punjab University, India.

Wu Jishan is a Professor in the Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, Chengdu, China. He was the Director of this Institute from 1983 to 1995. Currently he is Chairman of the Mountain Research Committee of the Geographic Society of China. He graduated from Nanjing University in 1962 and received his MSc. from the Geography Institute of the Chinese Academy of Sciences in 1966.

Professor Wu has done extensive research on mountain hazard mitigation in China. His main field of research has been on formation, dynamics, investigation, and mitigation of debris flow hazard. He has supervised many MSc dissertations and some students have completed PhDs under his co-supervision. Professor Wu also coordinated the Integrated Training on Mountain Risk Engineering project in China from 1995-1998 with support from ICIMOD. Over the past 35 years, he was coordinated 12 national and international projects on debris flow and landslide hazard mitigation. He has published over 30 research papers on debris flow studies in national and international journals, and he is the author or co-author of 7 books. Professor Wu is also the recipient of 6 scientific and technical awards from the state and provinces.

H. Yagi is an Associate Professor of Geomorpholoy at the Yamagata University, Japan. He obtained his Doctor of Science degree from Tohoku University, Japan, in 1986. Dr. Yagi also worked as a Lecturer in the National Defense Academy, Japan, from 1986 to 1996. His main interests are in the field of Neotectonics, Quaternary Geology, and landslide and regional study of Nepal. His field of research has spanned from northwestern Japan to Nepal and the adjacent Himalayan region. Dr

Yagi was also in charge of the Landslide Hazard Management Control Project at ICIMOD in 1995, a position to which he was deputed by the Japan International Cooperation Agency (JICA). Dr. Yagi has many publications to his credit in the field of geomorphology, hazard mapping and landslide studies.

Yin Chongqin is a senior engineer of the Institute of Debris Flow Prevention of Dongchuan city, Yunnan Province, China. He graduated from Kunming College of Water Conservation in 1963. Since then, he has worked as an engineer for 15 years in the Bureau of Water Conservation of Dongchuan city and remained with the Institute of Debris Flow Prevention.

After serving for more than 30 years in the fields of water conservation, soil erosion, and debris flow control, he has wide experience in the field of debris flow hazard mitigation and control. He was engineer in charge of 12 debris flow control projects in Yunnan Province, China. He was also involved in a study on the relationship between debris flow and precipitation in the Dongchuan area. Mr. Yin has published a number of research papers in national and international journals. He was recognised for his outstanding contribution by the Yunnan Provincial Government in 1989, and he also received a certificate for making an outstanding contribution to the development of engineering from the State Council in 1997.

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