



# **Ecohydrology of High Mountain Areas**

**Proceedings of the International Conference  
on Ecohydrology of High Mountain Areas,  
Kathmandu, Nepal  
24-28 March 1996**



**Editors**

**Suresh R. Chalise (Chief Editor), Andreas Herrmann,  
Narendra R. Khanal, Herbert Lang, Ludovit Molnar, Adarsha P. Pokhrel**



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## **Organized by**

UNESCO  
International Hydrological Programme  
Man and Biosphere Programme

His Majesty's Government of Nepal (HMG/N)  
Department of Hydrology and Meteorology

International Centre for Integrated Mountain Development (ICIMOD)  
Mountain Natural Resources' Division

German National Committee for the International Hydrological  
Programme of UNESCO and for the Operational Hydrology  
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## **In cooperation with**

The World Meteorological Organization (WMO)  
The National IHP Committee for Nepal  
The National IHP Committee for Slovakia  
The Steering Committee of the IHP FRIEND Project  
The International Association of Hydrological Sciences (IAHS)  
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**1998**

## Foreword

High mountain areas are the water towers of the world and sources of fresh water for large areas downstream. In Asia alone, seven of the world's largest rivers originate from the Tibetan plateau. Ancient human civilisations flourished around them. For the people and economies of the Hindu Kush-Himalayas as in most other mountain areas, water is used for three principal purposes: drinking water for humans and animals; water for irrigation of food and other agricultural crops; and, a very mountain-specific use: hydropower. Mountain areas are, however, also susceptible to water-related disasters due to increased orographic precipitation and steep slopes. Increasing populations and economic transformation have exerted considerable pressure on the land resources and vegetation of many mountain areas in the world.

Such changes in land use and land cover have brought about modifications in water flows, nutrients, sediments, and pollutants as well as loss of biodiversity almost everywhere in the mountains. However, the ecohydrological processes in high mountain areas, especially the role of natural processes, impacts of human interference and climate change on the availability of water, highland-lowland linkages, and sustainable use of water are poorly understood. There is, therefore, an urgent need for a better understanding of the vulnerability of the land-water system to human activities and climate change impacts in high mountain areas because of their fragile ecology and susceptibility to irreversible change.

For ICIMOD, as an international centre devoted to poverty alleviation and environmental conservation in the Hindu Kush-Himalayas, the development of a sound knowledge base on water resources of this region has been an important component of the programme of its Mountain Natural Resources' Division, and a long standing relationship has evolved with UNESCO's International Hydrological Programme (IHP), the World Meteorological Organization's Operational Hydrological Programme (OHP), and many other scientists in this field.

Considering the importance of mountain ecology and mountain hydrology, ICIMOD was happy to be invited to be one of the co-organizers of the International Conference on Ecohydrology of High Mountain Areas in Kathmandu from 24-28 March 1996. The main objective of the conference was to discuss outstanding issues concerning the ecohydrology of high mountain areas and to help specify the needs and relevant components for regional studies. It allowed more than 125 ecohydrologists from different regions in the world to establish contact with each other, clear evidence of the concern shown by the global scientific community about the extremely critical issues of ecohydrology. ICIMOD was entrusted with the publication of the abstracts submitted for the conference. Altogether 110 abstracts of papers were received for oral and poster presentation. All of them were published in the pre-conference Extended Abstract Volume and distributed at the time of the conference. Subsequently, ICIMOD was also entrusted with the task of publishing the Proceedings.

I am very happy that, with the present volume, we have also been able to publish the full Proceedings. I would like to thank my colleagues within ICIMOD, particularly Professor Suresh Raj Chalise who, as the Chief Editor, took the main responsibility for this publication on our behalf. Thanks are also due to Mrs Greta Rana, copy editor, and her team in the publication unit of ICIMOD. I would also like to thank Prof. A. Herrmann (Germany), Prof. H. Lang (Switzerland), Prof. L. Molnar (Slovakia), and Messers N.R. Khanal (Nepal) and A. Pokhrel (Nepal) for their editorial support and for helping us make this publication a reality.

On behalf of ICIMOD, I would also like to express my sincere thanks to the German IHP/OHP committee for providing financial support for the publication of this proceedings, Professor K. Hofius, Secretary, German IHP/OHP Committee; and Professor A. Herrmann of the Technical University, Braunschweig, for their personal interest and assistance in this respect.

This volume is the result of fruitful collaboration between ICIMOD and UNESCO's International Hydrological Programme and Man and Biosphere Programme. Thanks are due to Mr L.A. Mandalia, Regional Hydrologist, UNESCO, New Delhi, for coordinating the support from UNESCO and for his personal contribution. This document is also an outcome of our long-term collaboration with the Department of Hydrology and Meteorology (DHM) of HMG, Nepal, the principal local organizer for the Conference, and I would like to thank Mr. Kiran Shankar Yogacharya, Director General of DHM, and his colleagues for their active support and cooperation.

I would also like to take this opportunity to thank all those involved in the organization of the conference which was so successful. I also hope that the Kathmandu Declaration formulated by the Conference will provide a basis for future cooperation in improving scientific understanding and knowledge of the ecology and hydrology of high mountain areas; an area in which ICIMOD would be happy to contribute within its means and resources.

Finally, I would like to thank the authors. I have no doubt that their contribution to high mountain ecology and hydrology contained in this publication will provide very important references for all those interested in these subject areas, making this volume an important contribution to the knowledge of mountain ecology and hydrology and thus to the sustainable development of mountain natural resources for the improved economic well-being of the inhabitants of high mountain areas.

Egbert Pelinck  
Director General

## **Preface and Acknowledgements**

The high mountain environment is highly energised, dynamic, and extremely vulnerable to irreversible changes. Mountains are also unique ecologically and, as the abodes of snow and ice, they are also sources of fresh water for the sustenance of life in all forms in the mountains, as well as beyond. The ecology and hydrology of high mountain areas are therefore extremely important, and their complexities and diversities are a challenge to human understanding. The processes that govern the ecology and hydrology of high mountain areas and the interrelationship between them are yet to be properly understood. It is known that rapid population growth and an indiscriminate race for accelerated economic development have caused enormous pressure on the ecology and water resources of high mountain areas. However, until recently, the impacts of human activities were the principal causes of changes in the ecology and hydrology of high mountainous areas. Currently, the possible impacts of climate change, which are uncertain, have further added to the difficulties in improving our knowledge and understanding of the ecohydrology of high mountain areas.

The International Conference on Ecohydrology of High Mountain Areas was organized in Kathmandu from 24 - 28 March, 1996, to address these issues and to review the state of the knowledge on high mountain ecology and hydrology.

The conference in Kathmandu was one of the activities identified under UNESCO's IHP-V Project 2.4: Comprehensive Assessment of Surficial Ecohydrological Processes: and its principal objective was to discuss and exchange scientific knowledge on outstanding issues concerning the ecohydrology of high mountain areas, with special emphasis on regional issues.

Altogether 110 abstracts were submitted for oral and poster presentation at the Conference. These were published in a pre-conference extended abstract volume. During the conference, it was decided to publish the Proceedings and the editors were entrusted with this task, which was to be coordinated by the Chief Editor for ICIMOD.

This document contains 67 papers broadly covering all the relevant ecohydrological problems of the most complex high mountain ecosystems, together with the highlights of the conference. The scientific papers have been divided into six sections. These are given in the document abstract.

All the papers submitted for the publication were reviewed by experts before final editing. Due to the difficulties in communication and lack of time, it was not possible to send the edited version to all the authors for their comments before publication. However, authors were informed about changes when it was felt essential. Thanks are due to all the authors who cooperated by revising their papers. In many cases, authors were also consulted to obtain the complete form of the references cited. This took a considerable amount of time and, to some extent, delayed this

publication. Some delay in publishing this volume was also due to the change in final format of the paper. Originally authors were requested to follow the IAHS format. However, when it was decided that printing could not be done at UNESCO, but had to be undertaken by ICIMOD, all the papers had to be reformatted according to ICIMOD's in-house style.

We have also retained some incomplete references cited by authors as their full form could not be obtained, even up to the last minute. We believe that the importance of recording all information in this field warranted our doing so. Some papers submitted in French have also been included after translation of the abstracts and figure captions into English. In terms of language, we have accommodated the original terminology used by the authors as far as possible. We have also not abstracted those papers for which authors had not submitted abstracts. This is because, as mentioned before, a volume of extended abstracts of all the papers submitted for the conference had already been published before the conference in March 1996.

The papers are arranged in alphabetical order using the name of the first author for each theme. We have also not tried to impose a uniform style for the summary report of various sessions of the conference. We have presented the reports submitted by the co-chairpersons of the sessions in their original forms.

Prof. Herbert Lang of the Department of Geography, Swiss Federal Institute of Technology, Zurich; Prof. Andreas Hermann of the Technical University of Braunschweig; Dr. Ludovit Molnar of the Institute of Hydrology, Slovak Academy of Science, Slovak Republic; Mr. Adarsha P. Pokhrel of the Department of Hydrology and Meteorology of His Majesty's Government of Nepal; and Mr. Narendra R. Khanal of the Central Department of Geography, Tribhuvan University, Nepal contributed to the editing of the papers and were always available and willing to help. For this, the Chief Editor is extremely grateful. Thanks are also due to several other colleagues within and outside ICIMOD whose names could not be mentioned here but who have helped with their comments and assisted us so willingly during the editing. Thanks are particularly due to Prof. Pei Shengji, Head, Mountain Natural Resources' (MNR) Division, ICIMOD, Dr. Thomas Hofer, currently Watershed Management Advisor, MNR, and Mr. P.B. Shah, Soil Scientist, MNR, ICIMOD, for their assistance in editing some of the papers.

This publication would not have been possible without the support of our colleagues from the Documentation, Information, and Training Service (DITS) of ICIMOD. Special thanks are due to Mrs Greta Rana, Senior Editor, DITS, ICIMOD, for copy editing. Thanks are also due to Mr. Philip Pierce for his assistance in copy editing. The assistance of Mrs Greta Rana and Prof. A. Hermann of the Technical University of Braunschweig in editing the French papers is gratefully acknowledged. The editors are also thankful to Mr. A.K. Thaku and Mr. Dharma R. Maharjan, both of DITS, ICIMOD, for their cartographic and art work and layout and design, respectively.

Mrs Reeta Rana, Senior Secretary, and Mrs Sarita Joshi, Secretary, MNR Division, ICIMOD, also deserve special thanks for their patience and secretarial support for word processing this volume several times before the final draft was ready.

This publication would not have been possible without the active support of the German IHP/OHP Committee which also provided financial support for printing this volume. We are particularly grateful to Prof. K. Hofius, Secretary, German IHP/OHP Committee, and Prof. A. Herrmann for their continued support and encouragement. Thanks are also due to Mr. L. Mandalia, Regional Hydrologist, UNESCO Regional Office, New Delhi, for his continued support and for coordinating UNESCO's input during the preparation of this proceedings.

Finally, the Chief Editor would like to express his grateful thanks to Mr. Egbert Pelinck, Director General of ICIMOD, for his support and encouragement, and to Renu Chalise, his wife, for her understanding and support during the preparation of this volume. Without her continued support and encouragement it would not have been possible for him to complete this task.

On Behalf of the Editors

Suresh R. Chalise

Chief Editor

## **Abstract**

This document contains papers presented at a unique workshop on Ecohydrology of High Mountain Areas. Papers are divided into six topic areas, namely:

**Part A: Regional Issues on High Mountain Ecohydrology,**

**Part B: Network Design, Instrumentation, Data Collection and Processing Methodology and Modelling,**

**Part C: Atmospheric, Hydrologic and Ecological Interaction,**

**Part D: Role of Permafrost, Glaciers and Snow Cover,**

**Part E: Dynamics and Hazards of Erosion and Sedimentation, Ecosystems of High Mountain Areas and Landscape Processes, and**

**Part F: Water Quality and Limnological Issues.**

Most of the papers have individual abstracts. A volume of abstracts published prior to the conference is also available. Care has been taken to include as much information on references as possible, despite the problems of doing so for a document based on papers drawing on materials from a wide variety of essential languages.