Preface

To commemorate the outstanding role of George Kovacs in the international hydrological community, since 1992 the UNESCO International Hydrological Programme (UNESCO-IHP) and the International Association of Hydrological Sciences (IAHS) have jointly organized a series of biannual colloquia. The Kovacs Colloquium is traditionally held at UNESCO's headquarters just before the IHP Intergovernmental Council meeting. This book contains the papers presented by the invited keynote speakers at the eighth Kovacs Colloquium: *Frontiers in Flood Research*. The book provides new information and insights into key issues of present day flood research, with a particular focus on integrated flood risk management and sustainable development. The principal attraction of this book is the wide diversity of its contributions and the associated multidisciplinary approaches. The papers propose a scientific understanding of the flood phenomenon and of its potential impacts from the perspective of the engineering, operational, economic, social, hydrological and ecological aspects of flood research, and with the particular goal of effective flood risk management and cooperation between institutions, agencies, stakeholders and the private citizens who experience flood events.

Major floods are the most chronic and costly natural hazards in many countries across the world. Damage from flooding generally results from a combination of the colossal natural power of flood water with the recent increases of the vulnerability and population density of river flood plains. Despite new developments in flood related sciences and rigorous implementation of hazard-reduction policies, damages from flood disasters still continue to escalate. Losses resulting from floods extend far beyond economic hardship. Consequently, growing international attention focuses on innovative flood research and on integrated flood risk management.

The eighth Kovacs Colloquium: *Frontiers in Flood Research*, is therefore devoted to the current state of the art of the interdisciplinary activities committed to the key issues concerning flooding. It is also significant that the eighth Kovacs Colloquium contributes to the International Flood Initiative (IFI). The International Flood Initiative is an inter-agency programme led by UNESCO in cooperation with the World Meteorological Organization (WMO), the United Nations University (UNU), the United Nations Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN-ISDR)—in particular the UN-ISDR Platform for the Promotion of Early Warning (PPEW), and IAHS, and it has synergies with some other United Nations bodies. To address the key issues of flood, among other missions, the IFI provides a framework for directing research. It includes the physical aspects of floods, the socio-economic conditions and the preparedness of society to take the risks required to achieve the development objectives. It is also important to note that the eighth Kovacs Colloquium is strongly supported by the International Centre for Water Hazard and Risk Management (ICHARM). This International Centre was established on 6 March 2006 in Tsukuba (Japan) by the Government of Japan and under the auspices of UNESCO. As highlighted in the paper by Kuniyoshi Takeuchi, the establishment of this International Centre is a significant contribution to mitigating the impact of devastating water hazards across the world. Takeuchi emphasizes that the goals and

aims of the Centre are fully in line with UNESCO's objectives and programmes, and explains that ICHARM wishes to attain these goals by delivering to local communities the best practicable strategies that are appropriate to their specific local conditions.

Flooding is an entirely natural and common phenomenon that results from an increase in a river's flow beyond the point where its natural channel can contain the water. Floods rarely strike without some advance warning, and usually occur in places which have historically-formed flood plains. In the case of flash floods, flood waters occupy the flood plain for a matter of hours, whereas during the spring snowmelt runoff period a flood may stay for up to several months. A flood disaster happens when levels of flood preparedness are underestimated compared to the received flood water volume, either because it is greater than expected, or because of incomplete understanding of local hazards. Consequently, a primary means of reducing flood hazards corresponds to achieving better understanding of the magnitude and likelihood of extreme flows.

In anticipation of a possible increase of flood magnitudes, the paper by Cecilia Svensson, Jamie Hannaford, Zbigniew Kundzewicz and Terry Marsh discusses the major issues of trends in river floods and associated difficulties in detecting a clear signal in observations. The authors review different methodologies for detection of trends in river flow time series and discuss the main factors that may influence the results of trend analysis for floods. The most recent results in trend analysis of long series of river flow annual maxima from 195 gauging stations located worldwide are taken by the authors as a background for discussion of various issues related to the possible impacts of anthropogenic climate change and/or to man-induced influences on river flows at the catchment scale. The authors stress that while results from studies of climate modelling under the assumption of global warming often foresee an increase of floods, the results of trend analyses of observed river flows remain more ambiguous and generally do *not* confirm the expected increase in flood magnitudes. They argue that this discrepancy does not necessarily exclude a future increase of flood magnitudes and explain the different reasons why trends in long-term empirical records could be undetectable at present. Svensson *et al.* give examples illustrating the dependence of trend index estimates on different types of flood definition, on different periods of the same data record, on different types of test sensitivity indices and on different methods of estimation that may interact with climatological features. Furthermore, they emphasize the effect of decadal-scale oscillations on trend estimates. In conclusion, Svensson *et al*. encourage new initiatives to compile networks of pristine catchments with long river flow records so as to enable further investigation of any long-term increase in floods using convincing observational evidence. According to their perspective, this is indispensable to preserve scientific objectivity concerning the intricate problems of change detection.

Numerous factors affect stream flow fluctuations: the amount and type of precipitation, the nature and condition of the drainage basin, and climate are often counted among the most important. This implies a wide range of nonlinearly interacting scales. The paper by Andrea Rinaldo puts forward the idea that river basins constitute one of the most reliable laboratories for observation of how Nature works across a wide range of scales. Rinaldo reviews the outstanding issues and anticipates developments relevant to geomorphic flood research. He points out the central role of the problem of transport process modelling up to the catchment scale among the

general topics of flood research and emphasizes the term "*geomorphic flood research*" as analogous to catchment theory. As the major concerns of flood research directly include concepts of probability, so general transport models should include them as well. The focus of transport models is their capacity to reproduce observational evidence and to predict system functioning in the context of *unobserved* events. Thus, the unified formulation of transport by travel time distributions is proposed. While this formulation uses the information derived from geomorphology, it covers both flow and transport. The crucial role for this research of branching river networks, whose self-organized fractal patterns shows deep similarities across several orders of magnitude, despite hugely diversifying environments and forcing factors, is discussed. Rinaldo illustrates how to use the widely available geomorphic, hydrological and land-use data for the automated description of river network features. In conclusion, he argues for possible extensions of the theory and believes that issues of transport through fractal networks will, in the near future, strongly affect other research fields such as population biology and ecology.

Long-term cycles of high or low water, as well as rapid, seasonal water level fluctuations are characteristic for flood plains. Their ecology has adapted to such annual and longer term cycles. Wetlands and shallow surface water strongly depend on permanently fluctuating water levels to maintain their ecological balance and productivity. The marshes and swamps act as filters for the river system and allow the recharge of groundwater supplies. The paper by M. Besbes addresses the role of the (ephemeral) wadi floods in arid zone groundwater recharge, which has been recognized and observed over the last five decades in various places in the world. The Walnut Gulch experimental basin in Arizona, USA, and the Kairouan plain in Tunisia are two well-known case studies. Numerous studies on transmission losses concluded that 40 to 50% of the flood volume is lost in the wadi bed. This underlines the importance of the flood water infiltration mechanisms that are reviewed: percolation beneath the wadi, transfer mechanisms in the unsaturated zone, and propagation of the underground mound in the aquifer. The corresponding assessment methods are also reviewed: water balance, piezometric fluctuation, geophysical and geochemical methods, as well as the different models of flood routing infiltration in wadis. Nevertheless, our understanding of this phenomenon remains rather fragmentary, because of its complexity, and in spite of the numerous studies devoted to it and its importance for water management in arid zones. Besbes emphasizes that it is a truly interdisciplinary problem because it involves surface hydrology, non-saturated hydrodynamics, isotope hydrology, geophysics and hydrogeology. Unfortunately, it has usually been addressed by a compartmented, discipline-based approach; only one study has been performed with the help of the five cited disciplines, and studies involving two of these disciplines are very scarce. Besbes concludes that interdisciplinary research programmes are indispensable to obtain significant advances on this problem.

People often think of floods only in terms of the natural disaster and human and socio-economic losses, but floods can benefit the natural environment and sustain many ecosystems. Thus, integrated flood risk management is at the heart of the eighth Kovacs Colloquium. The aim is to develop flood risk management systems that essentially reduce the human and socio-economic losses while allowing the benefits from floods and flood plains to be maintained. The paper by Roland Price addresses the operational and engineering aspects of flood research and focuses on the three

primary phases of hazard reduction, operational management and post-event recovery. The author stresses that these phases provide a general framework for flood management and structures his paper as a comprehensive review with particular emphasis on innovative research and developments underway concerning the content and dynamics of each phase. He discusses examples of the various concepts of a flood, depending on its context, and acknowledges that the effective management of floods needs a multi-disciplinary approach. It naturally requires a strong integration of a huge diversity of data originating from observations and models addressing distinctly different processes, as well as that of possible engineering and technological solutions to managing floods. It also requires effective communication between the many stakeholders, including the general public, whether in terms of data monitoring systems, between models, consulting stakeholders, disseminating warnings, or giving attention to feedback on actions taken. Price concludes that achieving effective flood management is a non-trivial problem that requires collaborative efforts by stakeholders to share knowledge, experience and best practice, while taking responsibility for their own preparedness and procedural actions. Particular emphasis is given to the contribution of advanced information and communication technologies.

Hydrological monitoring and flood management in China are discussed by Jianyun Zhang and Zhiyu Liu. The authors first describe the particular predisposition of China to frequent and potentially harmful floods, mainly due to its geographical location and thus specific climate conditions combined with very rapid socio-economic development and population growth. To share the Chinese experience of flood control and management, the authors present some details of the operational systems employed giving particular attention to hydrological monitoring, flood forecasting and flood warning techniques. They acknowledge the very considerable efforts that have being made in China since the early 1960s to achieve a well-developed flood control engineering system; this has provided a basis for economic development and social stability. Jianyun Zhang and Zhiyu Liu emphasize that both structural and non-structural measures are very important for regular flood management, while non-structural measures such as hydrological monitoring and flood forecasting are most important in the case of extreme floods. In recent years these non-structural measures have been significantly strengthened and assisted by a powerful database management system and by the high-speed Wide Area Network. All these factors not only improve the precision of flood forecasts, but also improve the quality of the decision making. Nevertheless, the authors consider that flood control remains a big issue in China. They suggest that non-structural measures should be further improved and, in particular, with the help of new laws concerning social management, monitoring networks, warning and forecast systems.

By providing guidance for flood control operations, flood forecasting remains a key element in reducing flood damage. Its purpose is to interpret the relevant data, to estimate the amount of runoff that will occur, and to provide as much advance warning as possible of an impending flood. Although systematic river forecasts have often been initiated in the aftermath of an exceptionally devastating flood, river forecasts outside of the flood season are generally used to regulate reservoirs for various low-flow augmentation purposes, such as, for example, hydroelectric power production, irrigation and pollution assimilation. An operational flood forecasting system exploits a number of hydrological forecast models that have varying levels of complexity and

thus require different types and amounts of input information. Furthermore, no model is suitable for all drainage systems. It is important to note that the demands of flood forecasts have changed over time from a simple indication of the flood probability and severity to an accurate prediction of flood timing and magnitude at specific locations. Nowadays, in many countries of the world, flood forecasting and warning have evolved into a network of sophisticated forecast systems. The contribution by Robert Moore, Steven Cole, Victoria Bell and David Jones designates ungauged basins, extreme floods and uncertainty estimates as three major research challenges for further improvement in flood forecasting and warning. The authors emphasize that, when the basin is well gauged and the storm conditions are somewhat ordinary, lumped models assisted by site-specific calibration and real-time updating will continue to provide appropriate forecasts. However, for extreme storm conditions and for ungauged basins they demonstrate the superiority of distributed rainfall–runoff models, in particular for warnings and for flood-prone location identification. Different possible types of extreme storm are discussed raising questions about the dominant processes shaping the flood response in relation to model configuration and calibration. The use of distributed models for real-time flood forecasting largely evokes uncertainty estimation, which remains a challenge for both distributed and lumped models. In conclusion, Moore *et al.* discuss future advances in ensemble rainfall forecasting and the eventual benefits of risk-based decision-support systems for flood warning.

Mariele Evers' paper demonstrates that Decision Support Systems are indispensable for resolving the complexity of integrated flood management. She first stresses that an integrated approach has become crucial in present day flood protection. Integrated flood management requires extensive digital information on system complexity that reflects various causal nonlinear interrelationships and incorporates many inter-disciplinary issues that merge water and environment features. The importance of public involvement in management questions in the course of the river basin decision processes is emphasized. In the case of conflicting interests, Evers supports the development of alternative strategies for river and flood plain management to provide planners and policy makers with a variety of realistic options. In particular, she demonstrates the importance of a variety of data sets for resolving miscellaneous research questions and the adequacy of GIS-based technologies for many environmental and/or spatial analyses. Data-based or model-based Decision Support Systems become indispensable in helping the end-users with the relevant information in the planning process, which subsequently involves more and more diverse communication and interactive actions. The fact that the development of such sophisticated Decision Support Systems is normally very consuming in terms of time and finance is stressed, and therefore the development of new strategies and synergies allowing minimization of the costs and optimization of the benefits remains crucial. Examples of such possible improvements are discussed in detail. Coordinated data collection for the entire catchment area, and Internet-based modelling with modularization and with more flexible structures for flood-related data exchanges, are highlighted. Evers concludes that both water and environmental technologies can profit from each other within this integrated approach.

Historically people have lived along the edge of rivers and, in spite of the potential perils, the urbanization of flood plains continues. Economic development together with an increasing population has strengthened human efforts to constrict the active zone of

flood plains. Urbanization drastically modifies the natural drainage characteristics of catchments, mainly by increasing the volume and the rate of surface runoff. During intense rainfall events, this runoff often exceeds the carrying capacity of the town sewer system and thus yields flooding of the town. The contribution by J. C. Bertoni addresses the question of urbanization processes and urban floods. Urbanization is analysed in the world context, then in Latin America and undeveloped countries. Natural hazards and floods are analysed on the same scales and with the help of two city case studies: Argentina (2003) and El Salvador (2005). The main risk factors are identified with the help of an analysis of the increasing threat and vulnerability in Latin America. Vulnerability factors include societal: huge population concentration on reduced areas, unmonitored urbanization, overdevelopment of city peripheries, rural exodus; and technical factors: lack of urbanization policies at national, district and city levels, lack of professional training, non-structural techniques are ignored or disregarded; whereas global climate change might be an increasing threat factor. Global climate change is discussed with respect to the current scientific findings, as well as to its unbalanced presentation by the media. The latter might have the consequence that politicians and scientists are led to consider the climate change problem more important than the analysis of vulnerability. This could be interpreted as a convenient way to elude their immediate and local responsibility for risk management and the complexity of local vulnerability analysis. Bertoni emphasizes that the scientific and technical community of Latin America should deal with both the climatic change and the increasing urban vulnerability issues with a much more objective and balanced point of view.

Concurrent with the ongoing intensive development of flood plains that generally does not make allowance for the river's eventual return, the damage caused by flood disasters continues to escalate. A recent European directive proposal on flood estimation and management calls the attention of stakeholders to flood costs and their estimation. R. Nussbaum discusses this question from the insurer's perspective and experience. Combinations of micro and macroeconomic, *a priori* and *a posteriori* approaches are needed to evaluate the cost of damages. The current measures of flood damage costs are not exhaustive and statistical data are used by insurers (e.g. average cost) for potential damage modelling. In turn, the latter is used to model insurance portfolio management. This is illustrated with the help of a simulation assessing the number of floodable dwellings per river basin and extended to the whole French metropolitan territory. The current financing solutions for the repairs required after flood damage are reviewed. Flood insurance specifics are described and various schemes for extended natural hazards insurance coverage in Europe are presented. The question of arbitration to balance insurance and prevention costs raises an interesting problem due to some constraints in the French case. Indeed, the incentives for prevention measures can only be rather indirect with the help of insurance conditions, such as deductibles. An overview of the different problems and their current solutions is presented in conclusion.

Since, and even before the Bible story of Noah and the flood engulfing the entire Earth, in all the countries of the world people have recounted legends of enormous floods. The stories are certainly told in terms of how floods affect people's lives, but they also reflect public perception of the floods. The paper by Anna Vári and Zoltán Ferencz approaches flood research from the social perspective. It presents the results of

five empirical research studies of the Tisza River in Hungary focusing on public opinion after extreme flooding events during the period 1999–2003. The Tisza River basin is known to be one of the highest flood risk areas in Hungary, particularly its northeastern part. In addition to invoking climate change, the authors stress some reasons for flood aggravation in this region, such as new developments and farming practices in the flood-prone areas, deforestation and other land-use practices, the river regulation activities, and general ignorance of the natural drainage systems. They then underline the difficulties that governments face in developing suitable strategies for flood prevention and mitigation, which must meet technical, social and political requirements without exceeding the management capacity of a country. Thus, in the case studies considered, particular attention was given to the question of strengthening the resilience of the population to floods. Among the most important results of the investigations is a classification of the public's main sources of information about floods together with the corresponding level of useful knowledge in a crisis situation. Vári & Ferencz also grouped the public's opinion concerning the most important causes and consequences of flood damage jointly with the responsibility of the various intervening actors. The results obtained reveal public attitudes with respect to the main sources of possible conflicts and towards various possible flood prevention and mitigation strategies. Vári and Ferencz demonstrate a general divergence between the public's opinion and that of water management experts. Thus, the authors stress the importance of having alternative flood risk management policies, which should be evaluated not only from the perspective of technical rationality but also from the perspective of their social acceptability. Overall, this paper provides the reader with inspirational examples of how research focusing on the social perspectives of floods can assist policy decision makers.

In terms of the global ecosystem, floods should be viewed as a part of hydro-ecological cycles. Flood waters nourish wetlands in which the life of the natural environment has achieved a balance reliant on flooding. Maciej Zalewski discusses the significance of flood pulses for river ecosystem robustness. He approaches the matter of floods from the perspective of functional ecology. Regarding rivers as open ecosystems whose balance depends on permanent supply from the global ecosystem, he identifies flood pulses as mainly accountable for water quality and biodiversity. This paper first strengthens the previously evoked complex dependences of floods on climate change, ecosystem characteristics, basin geomorphology, catchment developments and river valley modifications. Then Zalewski suggests greater use of the potential of the self-regulation capacities of ecological processes. He is persuaded that the integrative understanding of hydrology at various space–time scales, together with the use of appropriate ecosystem processes, would have the most potential for successful sustainable water management. In particular, Zalewski focuses our attention on the role of the ecosystem's flood plains. Flood plains create a particular environment in which a variety of interacting organisms live and form an ecological community, called biocoenosis. The intrinsic property of the ecosystem's flood plains is the adaptability of their biocoenosis. In view of this, improvement of the process of conversion of nutrient and pollutant excesses into biomass and bioenergy, and thus optimization of flood plain functioning so as to increase the carrying capacity of the river basin towards the systems self purification, is suggested. Generally this paper illustrates how the new combined system approach, called ecohydrology, provides a

conceptual background for sustainable water and ecosystem developments. Furthermore, it stresses the vital role of effectively restored and periodically flooded flood plains in maintaining intact the entire biodiversity of catchments, particularly when facing the processes of global change.

The eighth Kovacs Colloquium, *Frontiers in Flood Research*, is followed by a Public Lecture, delivered by Eugen Z. Stakhiv, concerning the devastating impact of Hurricane Katrina on the State of Louisiana (USA) in 2005.

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