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Water Resources Systems—Hydrological Risk, Management and Development: A Summary

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INTRODUCTION

This volume contains 43 contributions authored by experts from 31 countries which is certainly a reflection of the importance of management and risk issues in water resources in many parts of the world. The publication has been organized into seven topics. The following is a brief summary of the main themes and results of the individual contributions, highlighting the overall findings of the symposium as far as hydrological risk and water management are concerned.

FLOOD RISK: ANALYSING TRENDS AND PROCESSES

The first set of papers relates to flood trends and flood processes. Kiem & Franks analyse temporal trends of flood risk across southeast Australia and relate flood occurrence to climatic indicators. They find that La Niña events are the dominant drivers of elevated flood risk and that an Inter-decadal Pacific Oscillation index is significantly related to multi-decadal epochs of elevated flood risk. These results point to the non-stationarity of flood risk and hence have marked implications for achieving robust flood estimates. Boychenko analyses the long-term trends of floods, droughts and other climatic anomalies and relates them to a number of causative factors. She finds that most of the anomalies are closely related to temperature fluctuations which allows her to construct a regression model to represent future scenarios associated with possible climate change. A similar analysis of climate factors is provided by Bárdossy *et al.* who analyse flood peaks of the River Tisza, Hungary, where most of the largest flood peaks of a 100-year record have occurred during the past four years. Large-scale atmospheric circulation patterns show non-stationary behaviour suggesting they are a possible explanation for the increase of floods in the Tisza basin although the results are not univocal. Kundzewicz takes a wider perspective of the same problem, analysing flood trends around the world. He finds that, in many places, flood risk is likely to grow due to a combination of anthropogenic and climatic factors although there are numerous counter-examples. A more prevalent finding is an increasing vulnerability to floods. This is consistent with the results of Ben-Zvi & Azmon who examine temporal trends in flood peaks in a number of regions in Israel. Except for one region, the changes are of local extent, if any. In some catchments flood peaks appear to increase, but they appear to decline in others.

While these contributions focus on isolating temporal trends and relating them to climatic indicators, the following two contributions examine individual flood processes more closely. Merz & Blöschl propose a framework for identifying the causative mechanisms of floods at the regional scale. They test the framework on flood data in Austria and are able to stratify the flood peaks into long-rain floods, short-rain floods, flash floods, rain-on-snow floods and snow-melt floods. All the flood types exhibit pronounced seasonal patterns and their relative contribution changes with flood magnitude. Tetzlaff *et al.* analyse the causative factors of two major flood events in Germany, the 1342 and the 2002 floods, by relating results from a dynamic precipitation model to observed (or estimated) flood discharges, which allows them to back-calculate the most important hydrological characteristics of the flood events.

MODELLING FLOOD RUNOFF

The second set of papers presents a variety of methods for estimating flood flows. Some of them are set in the wider context of socio-economic activities. Bardsley & Liu propose a method for rainfall–runoff model construction using manual calibration of hydrograph lag and length, with automated calibration of a large number of "hidden parameters". They argue that this procedure is amenable to land-use change applications, and hence they test it for catchments in New Zealand and China which have experienced land-use change. Madsen *et al.* propose a procedure of using water level data and stream flow data to update the model states of a flood forecasting model based on ensemble Kalman filtering. Using a case study in northwestern Italy, they show that the procedure significantly improves the model's forecast skills as compared to forecasting without updating. Shamseldin & O'Connor combine the river flow forecasts of two individual multiple-input single-output river flow routing models. They use a weighted average method and an auto-regressive model error updating procedure to combine the outputs of these two models into one prediction. However, the performance of the combined model is not significantly better than that of the best of the individual models. Awan analyses the different meteorological causes of floods in Pakistan. He then reviews the suite of modelling approaches used in Pakistan and the more practical aspects of instrumentation and dissemination of the forecasts.

A more local study is provided by Wang *et al.* who estimate the flood risk for a hydropower project in China. Specifically they calculate the combined hydrological and hydraulic risk of the closure of a diversion channel for different times of the year and find a strong seasonal dependency of this risk. Kuchment *et al.* derive a flood frequency model combining a stochastic precipitation model and a deterministic rainfall–runoff model. They use the model to examine the effect of changed land-use conditions on the flood frequency characteristics of a catchment in southwestern Russia.

In a much broader context, Booij combines hydrological, hydraulic and economic models to support decision making in flood control and ecosystem upgrading measures. He evaluates scenarios for the Red River basin in Vietnam and China. Some of these scenarios decrease flood damage but they may also decrease total revenues. The paper by Dao & Kaoru deals with a part of the same river basin. However, they adopt a wider view of the socio-economic issues of both flooding and the lack of flooding as a result of a channel constructed to divert the Day River. Their findings,

based on a comprehensive questionnaire campaign, suggest that local people are highly inventive and adapt to the regular occurrence of floods and so are well prepared to cope with regular flooding.

DROUGHT RISK: ANALYSING TRENDS AND PROCESSES

Shimokura & Shibano examine the temporal trends of baseflow recession over a 70-year period in three forest restoration catchments in Japan. They find that flow recessions have become flatter in recent years and interpret this as a result of the development of forest soils associated with the growth of the forest over the years. A somewhat similar study is reported by Sugiyama *et al.* who compare flow regimes in the upper reaches of streams in the temperate zone (eastern Japan) with those in the tropical monsoon zone (western Thailand). They find vastly different low flow characteristics and give some guidance on the choice of low flow indices to be used for the design of water resources facilities in these contrasting climates.

Chang & Wang investigate precipitation changes in Taiwan during the twentieth century. They find a remarkable consistency between major drought episodes and sulphur rich eruptions of volcanoes around the world. They interpret the causal relationships in terms of the effect of aerosols in the atmosphere on radiative processes. Stancalie *et al.* analyse the increasing aridization in southern Romania where nine severe droughts have occurred during the past 20 years. They use a coal basin in the area as an example to demonstrate that, to increase ecosystem resistance to long drought effects, stress elements such as anthropogenic activities must be reduced.

The final paper of this section leads on to the reservoir management section of this volume. Kiem & Franks investigate drought risk by analysing the performance of a water storage reservoir in southeast Australia. The find one particular climate index, the Inter-decadal Pacific Oscillation index, to be representative of drought variability. They compare three adaptive management strategies with current practice and conclude that the adaptive strategies based on climate index forecasts can improve drought security.

MANAGEMENT OF RESERVOIR SYSTEMS

Brass & Schumann propose an adaptive model for optimizing a reservoir system which facilitates frequent adjustments of the management strategy. They illustrate the potential of the approach with a hypothetical five reservoir system and analyse possible climate change and demand change scenarios. Arumugam *et al.* present a framework of water allocation for multiple uses based on annual water contract terms and ensemble forecasts of reservoir inflows using climatic indices. The feasibility of the approach is demonstrated for a reservoir in Brazil. An alternative method that uses control curves is proposed by Adeloye *et al.* Hypothetical reservoir simulations using the proposed method suggest that, without prior knowledge of inflows, the resulting reservoir performance was acceptable in that recovery was rapid and emptiness was avoided. The authors suggest that control curves provide a much easier and cheaper, yet effective, alternative to operating policies which often require inflow forecasting to be effective.

Cancelliere *et al.* present a methodology for deriving operating rules for a multi-purpose reservoir system based on optimization and neural network techniques. They test the method for different hydrological scenarios. In a similar study, Umamahesh develops the operating policy for an irrigation reservoir in India and compares three models of different complexities using simulations. His results suggest that the most complex model performs best. Hanasaki *et al.* propose a method for deriving reservoir operating rules from globally available data sets and test the method for a river in Thailand. The authors conclude that this method provides more reliable estimates of the seasonal distribution of the global water resources and its inter-annual fluctuation than existing procedures.

WATER RESOURCES MANAGEMENT POLICIES

A comprehensive discussion of the role of dams in integrated water resources management is provided by Petersson & Ostrowski. They suggest that the main challenge of the coming years will be to adapt existing methods of multi-criteria decision-support to water development in general and to dams in particular, and to ensure their practicality and acceptability in a planning context. Murty provides a historical perspective of the national water policies in India, focusing on the amendments to previous policies of the most recent legislation. In a similar vein, Loebis reports on the past and current water management policies in Indonesia. He gives a detailed account of the change of paradigm that is taking place when moving from a centralized water policy to a decentralised participatory water policy, and identifies the role of the stakeholders in the new paradigm.

At a much smaller scale, but in a similar setting, Adi proposes water and soil conservation strategies to reduce soil erosion and to maintain the water quality of a West Java lake. He does this by introducing a ranking of priority development for soil and water conservation, from seasonal crop areas, to forested areas, and perennial crops. He emphasises the need for a water management board to coordinate the diverse water related activities in the catchment area.

WATER RESOURCES MANAGEMENT: METHODS AND CASE STUDIES

Hughes discusses approaches to quantifying environmental flows that appear to still rely heavily on expert judgement in the absence of sufficient hard data concerning biotic responses to changes in river flow regimes. He discusses implementation issues for rivers across South Africa in the context of the water resource management structures and legislation that exist in South Africa. Rabi *et al.* examine the spatio-temporal variability of rainfall and resulting groundwater recharge in the Jordan River basin including the effects of a recent drought year. They then discuss the implications for water management vis-à-vis the complex hydro-political situation in the area involving Palestine and Israel.

Jimoh & Ayodeji analyse the effects of future interbasin water transfers on the water management of a reservoir in Nigeria. Based on a simulation study they

conclude that the water transfer will increase hydropower generation but at the same time increase the flood risk downstream of the dam. To reconcile these competing issues they propose structural flood protection measures. Ikhile & Ikhile examine irrigation activities in a Nigerian catchment and relate them to climate fluctuations. They report that the government has responded promptly to the evidence of decreasing precipitation and has made provisions for accelerated irrigation projects.

Herath *et al.* present a simulation study in which they examine the effect on the water balance components of infiltration facilities in the suburbs of Tokyo. They conclude that the infiltration facilities both increase the groundwater recharge and reduce the flood flows, effects that are considered favourable in the context of water resource management of this type of urban system. In the context of assessing water resources at much larger scales, Magome *et al.* propose a suite of methods for monitoring the seasonal variation of water storage in reservoirs. They use satellite images to extract the water surface area, and satellite altimetry to obtain estimates of the lake level, and test the method for a large reservoir in Ghana.

INTEGRATING WATER RESOURCES MANAGEMENT

In this final section, Loáiciga presents a method for calculating sustainable groundwater pumping rates in terms of diverse economic and hydraulic factors. The method maximizes the expected value of the net revenue subject to a number of constraints that ensure consistency with the definition of sustainability chosen. He illustrates the feasibility of the approach by a hypothetical example. Fashchevsky & Fashchevskaya propose an approach for assessing priorities in the use of water resources in a catchment, based on assigning water resources to different uses including drinking water supply, industry, irrigation, recreation, and aquatic ecosystems. Their contribution then focuses on the determination of environmental flows in an integrated management context, illustrated by an example from the Volga River. Kondratyev presents a somewhat similar method, but for an urban setting, for choosing optimum strategies for managing the urban water bodies in St Petersburg. The economic returns for the water users are maximized under the constraints that water quality and the ecological state need to be maintained. Brilly & Globevnik discuss several strategies of integrated and sustainable management of the water resources in a catchment shared by Slovenia and Croatia. They focus on reconciling several conflicting interests including drinking water supply, food production, tourist development and landscape value.

Yang *et al.* is a fine example of the role of water management in balancing the variability of water resources in both time and space. Northern China is currently experiencing a water shortage as a result of decreasing rainfall trends, despite frequent flooding. Yang *et al.* discuss a suite of measures including conservation measures and water transfers to balance water shortage and increasing demand. A similar discussion is provided in Sharma for the case of northeastern India where deforestation has resulted in water scarcity because of reduced recharge to aquifers. Sharma suggests that a dramatic shift in management practice is needed, including replacement of the current practice of shifting cultivation by sustainable farming systems.

At a much broader scale, Shiklomanov & Balonishnikova contrast the Conventional and the Sustainable Development scenarios of world water use and water availability. While in the former, world water use would increase by more than a third in the next 20 years, in the latter water use would be almost stable. Whichever scenario will be more appropriate, the authors emphasize the need for multi-facetted solutions to water problems around the world.