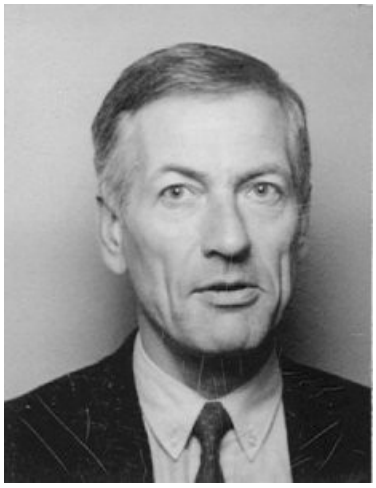
Preface



The Late Joop Steenvoorden

This volume comprises the set of full papers submitted to Symposium S3 on Groundwater Resources Sustainability Indicators held on Wednesday 6 and Thursday 7 April, 2005 at the VIIth IAHS Scientific Assembly, Foz do Iguaçu, Brazil. It is dedicated to the memory of Joop Steenvoorden who, as President of the IAHS International Commission of Water Quality (ICGW), had taken a leading role in developing the ideas for a meeting on sustainability indicators for groundwater resources, but who very sadly and unexpectedly passed away on 13 June 2004. Joop was instrumental in involving not only ICWQ in this meeting, but also in facilitating the participation, support and sponsorship of ICGW (International Commission of Groundwater), ICWRS (International Commission of Water Resources Systems), UNESCO-IHP (UNESCO International Hydrological Programme), WWAP (World Water Assessment Programme) and IAH (International Association of Hydrologists), which significantly enhanced the Symposium. This was very much typical of Joop's activity on behalf of the Commission, and ICWQ will sorely miss his expertise, enthusiasm and energy, from which it has greatly benefited.

Groundwater indicators are based on monitoring and assessment programmes, and are helpful for many reasons. For example, indicators may be used to identify the state of the groundwater system, both in terms of its quantity and quality, and its evaluation over time and space. They also facilitate communication between policy makers and the general public. Indicators should be selected and developed which provide information on the threat to groundwater systems from the point of view of societal and ecological needs. The idea behind this symposium was to promote the exchange of ideas and experience, in the area of groundwater sustainability indicators, between those engaged in river basin studies from this perspective. The papers in this volume range over somewhat wider aspects of groundwater sustainability than perhaps suggested by the original brief for Symposium S3. Nonetheless, they summarize much of the state of the art in the field of groundwater sustainability and its indicators, and have been grouped into five main topics.

The first of these provides an introduction to the main theme of the Symposium and focuses on the general issues of the indicators and indices appropriate for classification. The paper by Jaroslav Vrba and his colleagues describes the seminal contribution of the UNESCO/IAEA/IAH Working Group on Groundwater Resources Sustainability Indicators, which has applied a DPSIR (D, Driving forces; P, Pressures; S, States; I, Impacts; R, Responses) approach in finalizing a set of indicators that balance scientific and policy-based considerations. The use of sustainability indicators, such as sinkhole formation, saline intrusion, decrease in river and spring flow, and vegetation

die-off, as a means of classifying groundwater in South Africa is clearly illustrated by Roger Parsons and Johan Wentzel, while a system of ecological indicators, based on a range of indices (damage, pollution, hydrogeochemistry, transport and migration, interaction), is proposed by Anna Belousova as a basis for risk assessment of groundwater pollution. Wu Qiang and Wang Zhi-Qiang put forward two systems of groundwater sustainability indicators—one to provide safety status warnings in relation to groundwater exploitation and the other to assess the bearing capacity of the groundwater environment—and illustrate these with case studies from China. N. S. Ognianik and his colleagues discuss the Ukrainian hydroeconomic complex in the context of sustainable development and with reference to criteria such as the supply of renewable water resources of satisfactory quality, the efficiency of water resources use and an index of water resources risk. In major river systems, such as the Brahmaputra of northeastern India, U. C. Sharma and Vikas Sharma argue that groundwater sustainability indicators show spatial and temporal variations and may be divided into the five categories of socio-economic, meteorological, environmental (relating to floods and droughts), resilience and policy domain and management factors.

The insight which mathematical and numerical models can provide into sustainability and its indicators is the second topic addressed in this volume. Mary Hill's paper highlights four important general concerns in using modelling for this purpose, which comprise the mathematical and numerical accuracy of the model, the accuracy of the data used in model development, the information which observations provide in relation to sensitivity analysis of model predictions, and the existence of plausible alternative models. Specific examples of the use of modelling to analyse groundwater sustainability are presented by Jonathan Whittier and Thomas Maddock for the riparian habitats of the Lower San Pedro River in Arizona, USA, where water table levels near the river have declined due to pumping, and by Maciek Lubczynski for the Sardon area in Spain and the Serowe area in Botswana, which have contrasting hydrogeological conditions and different degrees of socio-economic impact. The paper by Abdulghani Hasan and Anass Rasheed reports how GIS techniques in combination with surface runoff and groundwater models have been employed to assess the potential of check dam construction and rainwater harvesting to replenish groundwater levels in the in the Bashiqa Region of Iraq.

Groundwater sustainability has to be seen within the context of wider hydrological conditions and their variability. Papers on this third theme include the study of the Northwest region of Buenos Aires Province by Eduardo Kruse and his colleagues, who document how in wet periods the depth to the water table is relatively shallow and inundation of flatlands leads to adverse effects on agricultural production, while in dry periods the depth to the water table is approximately doubled, the area of ponds reduces significantly and satisfaction of agricultural demand for water becomes difficult. Groundwater may be particularly prone to overexploitation during drought periods, and M. Krishnaveni and her colleagues have undertaken statistical analysis of 30 years of groundwater level data from 80 observation wells in the Palar Basin in Tamil Nadu State, India, to generate a drought risk map for groundwater in this region. Understanding how surface water is recharged to aquifers is an important aspect of assessing their sustainable use, and Liu Xiangchao shows the potential of several

tracers (δD, δ18O, pH and conductivity) for elucidating the nature of surface runoff–groundwater interactions in the Huaishahe Basin in Beijing, China.

The impact of agriculture, and especially irrigation, on groundwater sustainability is the fourth topic addressed in this volume. Rae Mackay and his colleagues have investigated how uncontrolled exploitation and over-irrigation of groundwater in shallow alluvial aquifers in semiarid Northeast Brazil is leading to soil salinization and degradation of the groundwater. However they also demonstrate that an understanding of the important links between hillslope runoff, groundwater use, subsurface controls and the annual and longer-term variations in water availability and water quality, obtained through detailed physical studies, may allow successful farm and community level approaches to sustainable use. J. A. Morábito and his colleagues explain the use of performance indicators, which take into consideration groundwater and surface water use efficiency, in analysing irrigation water use in the Province of Mendoza that has more than 20% of the total irrigated land in Argentina, while Qiuhong Tang and his colleagues discuss the hydrological processes that occur in the intensively cultivated alluvial plain of the arid upper Tarim River in central Asia.

Issues associated with water quality and groundwater contamination are an important aspect of sustainability and represent the final topic covered in this volume. Serwan Baban and his colleagues highlight the role of nitrate leaching in contaminating groundwater in part of the Azraq Basin, Jordan through a GIS study which estimated considerable losses from cesspools and from agricultural land. The study of the Nasunogahara Basin in the Tochigi Prefecture, Japan, by Hiroaki Somura and his colleagues demonstrates, through modelling, that influent load from a concentrated livestock farming area may have a considerable impact on the NO_3-N concentration of groundwater, but also reveals the role of advectional transport from the upper to the lower part of the study catchment. P. Rajendra Prasad and his colleagues analyse the role of water quality and groundwater fluctuations in understanding sustainable development and management of groundwater resources in the coastal and urban aquifers of Visakhapatnam, India, while Marta Paris and her colleagues undertake a more local investigation of how wetlands may be used in mediating the local impact of industrial effluent in Santo Tomé, Provincia de Santa Fe, Argentina. The structure of the saline–freshwater interface in the Indian coastal delta complexes is discussed by Indugula Radhakrishna and provides an important context for estimating fresh groundwater reserves and sustainability.

Many individuals have been involved in putting together this Proceedings, and I would particularly wish to express my thanks to Ricardo Hirata, Eduardo Kruse and Jaroslav Vrba, who as co-convenors have assisted significantly with the selection, refereeing and editing of papers for this volume, and to Penny Farnell and Cate Gardner at IAHS Press for preparing the papers for publication as a Red Book.

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