Preface

Water resource systems planning and management issues are rarely simple. Demands for reliable supplies of clean water to satisfy the energy, food, and industrial demands of an increasing population and to maintain viable natural ecosystems are growing. This is happening at the same time changes in our climate are increasing the risks of having to deal with too little or too much water in many river basins, watersheds, and urban areas. Societies are becoming increasingly aware of the importance of water and its management and use; their governing institutions are becoming increasingly involved in water resources development and management decision-making processes. To gain a better understanding of the complex interactions among all the hydrologic, ecologic, economic, engineering and social components of water resource systems, analyses based on systems perspectives are useful. While analyses of such complex systems can be challenging, integrated systems approaches are fundamental for identifying and evaluating options for improving system performance and security for the benefit of all of us.

Just how well we are able to plan and manage our water availability, quality, and variability is a major determinant of the survival of species, the functioning and resilience of ecosystems, the strength of economies, and the vitality of societies. To aid in the analysis of planning and managing options, a variety of modelling approaches have been developed. This book introduces the science and art of developing and applying various modelling approaches in support of water resources planning and management. Its main emphasis is on the practice of developing and using models to address specific water resources planning and management issues and problems. Their purpose is to provide relevant, objective, timely and meaningful information to those who are responsible for deciding how we develop, manage, and use our water resources.

Readers of this book are not likely to learn the art of systems modelling and analyses unless they actually do it. The modelling approaches, examples and case studies contained in this book, together with the exercises offered at the end of most chapters, we believe and hope, will facilitate the process of becoming a skilled water resources systems modeler, analyst and planner. This has been our profession, indeed our hobby and source of enjoyment, and we can highly recommend it to others.

Water resource systems planning and management is a multidisciplinary activity. The modelling and analysis of water resources systems involves

inputs from the applicable natural and social sciences and from the people, the stakeholders, who will be impacted. It is a challenge.

Although we have attempted to incorporate into each chapter current approaches to water resources systems planning and analysis, this book does not pretend to be a review of the state-of-the-art of water resources systems analysis. Rather it is intended to introduce readers to the art of developing and using models and modelling approaches applied to the planning and managing of water resources systems. We have tried to organize our discussion in a way useful for teaching and self-study. The contents reflect our belief that the most appropriate methods for planning and management are often the simpler ones, chiefly because they are easier to understand and explain, require less input data and time, and are easier to apply to specific issues or problems. This does not imply that more sophisticated and complex models are less useful. Sometimes their use is the only way one can provide the needed information.

In this book, we attempt to give readers the knowledge to make appropriate choices regarding model complexity. These choices will depend in part on factors such as the issues being addressed and the information needed, the level of accuracy desired, the availability of data and their cost, and the time required and available to carry out the analysis. While many analysts have their favourite modelling approaches, the choice of a particular model and solution method should be based on the knowledge of various modelling approaches and their advantages and limitations. There is no one best approach for analyzing all the issues one might face in this profession.

This book assumes readers have had some mathematical training in algebra, calculus, geometry and the use of vectors and matrices. Readers will also benefit from some background in probability and statistics and some exposure to micro-economic theory and welfare economics. Some knowledge of hydrology, hydraulics and environmental engineering will also be beneficial, but not absolutely essential. Readers wanting an overview of some of natural processes that take place in watersheds, river basins, estuaries and coastal zones can refer to the Appendices (available on the internet along with the book itself). An introductory course in optimization and simulation methods, typically provided in either an operations research or an economic theory course, can also benefit the reader, but again it is not essential.

Chapter 1 introduces water resources systems planning and management and reviews some examples of water resources systems projects in which modelling has had a critical role. These projects also serve to identify some of the current issues facing water managers in different parts of the world. Chapter 2 introduces the general modelling approach and the role of models in water resources planning and management activities. Chapter 3 begins the discussion of optimization and simulation modelling and how they are applied and used in practice. Chapter 4 focuses on the development and use of various optimization methods for the preliminary definition of infrastructure design and operating policies. These preliminary results define alternatives that usually need to be further analyzed and improved using simulation methods. The advantages and limitations of different

optimization/simulation approaches are illustrated using some simple water allocation, reservoir operation and water quality management problems.

Chapter 5 extends this discussion of optimization to problems characterized by more qualitative objectives and/or constraints. In addition, it introduces some of the more recently developed methods of statistical modelling, including artificial neural networks and evolutionary search methods including genetic algorithms and genetic programming. This chapter expects interested readers desiring more detail will refer to other books and papers, many of which are solely devoted to just these topics. Chapters 6 through 8 are devoted to probabilistic models, uncertainty and sensitivity analyses. These methods are useful not only for identifying more realistic, reliable, and robust infrastructure designs and operating policies for the given hydrological variability and uncertain parameter values and objectives but also for estimating some of the major uncertainties associated with model predictions. Such probabilistic and stochastic models can also help identify just what model input data are needed and how accurate those data need be with respect to their influence on the decisions being considered.

Water resources planning and management today inevitably involve multiple goals or objectives, many of which may be conflicting. It is difficult, if not impossible, to please all stakeholders all the time. Models containing multiple objectives can be used to identify the tradeoffs among conflicting objectives. This is the information useful to decision-makers who must decide what to do given these tradeoffs among conflicting performance criteria that stakeholders care about. Chapter 9 on multi-objective modelling identifies various types of economic, environmental and physical objectives, and some commonly used ways of including multiple objectives in optimization and simulation models.

Chapter 10 is devoted to various approaches for modelling water quality in surface water bodies. Chapter 11 focuses on modelling approaches for multiple purpose water quantity planning and management in river basins. Chapter 12 zooms into urban areas and presents some ways of analyzing urban water systems. Finally, Chap. 13 describes how projects involving the analyses of water resource systems can be planned and executed.

Following these thirteen chapters are four appendices. They are not contained in the book but are available on the internet where this book can be downloaded. They contain descriptions of (A) natural hydrological and ecological processes in river basins, estuaries and coastal zones, (B) monitoring and adaptive management, (C) drought management, and (D) flood management.

For university teachers, the contents of this book represent more than can normally be covered in a single quarter or semester course. A first course might include Chaps. 1 through 5, and possibly Chaps. 9 and 10 or 11 or 12 or 13 depending on the background and interest of the participants in the class. A second course could include Chaps. 6 through 8 and/or any combination of Chaps. 10 through 12, as desired. Exercises are offered at the end of each chapter, and instructors using this text in their academic courses can contact the authors for the solutions of those exercises if desired.

Many have helped us prepare this book. Jery Stedinger contributed to Chaps. 6, 7 and 8, Nicki Villars helped substantially with Chap. 10, and Jozef Dijkman contributed a major portion related to flood management. Tjitte Nauta, Laura Basco Carrera and Thijs Stoffelen contributed to Chap. 13. Others who offered advice and who helped review earlier chapter drafts include Vladan Babovic, Martin Baptist, Henk van den Boogaard, Herman Breusers, Harm Duel, Herman Gerritsen, Peter Gijsbers, Jos van Gils, Simon Groot, Karel Heynert, Joost Icke, Hans Los, Marcel Marchand, Tony Minns, Erik Mosselman, Arthur Mynett, Roland Price, Erik Ruijgh, Johannes Smits, Mindert de Vries and Micha Werner. Engelbert Vennix and Hans van Bergem created most of the figures and tables in this book. We again thank Deltares and all these individuals and others who provided assistance and support on various aspects during the entire time in 2005 and when this second edition was being prepared.

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Most importantly, we wish to acknowledge and thank all our teachers, students and colleagues throughout the world who have taught us all we know and added to the quality of our professional and personal lives. We have tried our best to make this book error free, but inevitably somewhere there will be flaws. For that, we apologize and take responsibility for any errors of fact, judgment or science that may be contained in this book. We will be most grateful if you let us know of any or have other suggestions for improving this book.

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