Hydrology and Floodplain Analysis

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Dedication

To Cindy, Eric, and Courtney, to my parents for their guidance, and to my teachers, and to all my students over the past 35 years.

P.B.B.

To My Family

To my wife, Jean, and to our children William, Ellen, Laura, Anne, and Kimberly, and to my parents

B.E.V.
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The field of hydrology is of fundamental importance to civil and environmental engineers, hydraulic engineers, hydrogeologists, and other earth scientists because of the overall significance of water in modern society. Topics include water supply, major floods, droughts and their management, urban drainage and stormwater issues, floodplain management, climate change, and water quality impacts. In recent years, hurricanes and storm surge have caused significant coastal disasters, especially in coastal areas where urban development has expanded rapidly. This book was written to address the computational emphasis of modern hydrology both at an undergraduate and graduate level, and to provide a balanced approach in terms of theory and important applications in hydrologic engineering and science. A particular emphasis in the sixth edition is the incorporation of new examples, homework, and computer modeling applications.

Increasing use and sophistication of computer software and the accessibility of large-scale data have revolutionized the daily practice of hydrology. The impact of transferring online data from governmental and scientific sources to the practicing hydrologist or student has been phenomenal. Hydrologic rainfall data, digital terrain models, and mapping software linked with hydrologic modeling now allow complex problems to be solved efficiently. Geographical information systems (GIS) and radar rainfall have greatly improved our ability to predict hydrologic response. A number of major improvements have been made to existing hydrologic models, such as HEC-HMS, HEC-RAS, and EPA SWMM. These advances are highlighted with examples in the sixth edition. Important websites and links currently used routinely in hydrology are listed in Appendix E and can also be found at the textbook website: hydrology.rice.edu. While the entire textbook was updated with many new examples and new homework problems, the following lists the most important updates incorporated for the sixth edition.

- Chapter 6: New SWMM5 example embedded in a real case study of the application of decentralized stormwater controls
- Chapter 7: New HEC-RAS discussion with a new detailed example
- Chapter 8: New examples in groundwater modeling
- Chapter 10: New chapter on GIS in Hydrology with a new example
- Chapter 11: Completely updated and includes new Vflo® example
• Chapter 12: New chapter highlighting flood policy evolution in the United States.
• Chapter 13: New chapter on water resources case studies across America.

The sixth edition of the text is still divided into three main sections. **The first section**, consisting of the first four chapters, covers traditional topics in hydrology related to the water balance such as: (1) hydrologic principles, hydrologic cycle, and measurement techniques, (2) hydrologic analysis using hydrographs for rainfall-runoff, (3) statistical and flood frequency analysis, and (4) hydrologic and hydraulic flood routing methods. These chapters provide a lot of the basis for more applied modeling applications in later chapters of the text. Many new figures, examples, and homework problems have been included throughout.

**The second major section.** Chapters 5 through 9, is designed to apply hydrologic theory and available hydrologic modeling techniques to several areas of engineering hydrology and design: watershed analysis, floodplain delineation, urban stormwater, ground water, and drainage design. The latest methods and computer models are described in enough detail for practical use. Updated examples and new case studies are also provided. Chapter 5, Hydrologic Simulation Models, has been updated to include the latest versions of the HEC-HMS model. Chapter 6, Urban Hydrology, presents methods and reviews of available computer models for pipe and open channel storm drainage systems. The Storm Water Management Model (SWMM5) is highlighted with a new watershed planning example. Chapter 7, Floodplain Hydraulics, first covers open channel flow concepts, including uniform flow and critical flow. These concepts form the basis for various hydraulic analyses such as water surface profile computations in a hydraulic model, HEC-RAS, described in detail with a new case study demonstrating the power of the model in steady and unsteady mode to evaluate natural floodplains. Chapter 8 presents ground water hydrology as a stand-alone chapter, including flow in porous media, aquifer properties, well mechanics, and computer applications. Governing equations of flow are derived and applied to a number of ground water problems, and a new example has been added. Chapter 9 is a comprehensive chapter on design applications in hydrology. It addresses design rainfall, small watershed design, hydraulic design, detention pond design, detailed culvert design, and floodplain mitigation design issues.

**The final major section** includes four chapters (10, 11, 12, and 13) that have been completely redone to cover a variety of interesting and relevant topics such as GIS data analysis and hydrologic computation, radar rainfall and watershed evaluation, severe storm impacts and flood management, and water resource case studies from across the United
States. No other hydrology textbook presents this type of material all in one place. Chapter 10 presents current geographic information systems (GISs) and digital elevation models (DEMs) as important tools for watershed and land use analysis, hydrologic modeling, and advanced floodplain delineation. Many useful hydrologic datasets and software are now widely available in high-resolution digital form on the web (see Appendix E). Chapter 11 depicts some of the latest technology on the use of NEXRAD radar data to estimate rainfall intensities over watershed areas. Radar rainfall has greatly improved our ability to predict rainfall patterns over a watershed and offers real advantages for hydrologic flood alert systems.

Chapter 12 is a new chapter on flood control and risk management in the United States and includes a number of new examples from across the country, including discussion of Mississippi River flood control strategies and the surge mitigation response in New Orleans from Katrina. Chapter 13 is also a new chapter for the sixth edition, and details major water resources projects around the United States with detailed case studies from the Colorado River, the Columbia River, major flooding issues in Texas, and a water rights issue between Florida and Georgia.

The sixth edition of the text should provide the civil or hydraulic engineering or science student with all the necessary theory to understand principles of hydrology, hydrologic modeling, floodplain hydraulics and analysis, data analysis, and water resources management in the modern digital world. The student or practicing engineer should find the book a useful reference for hydrologic methods, current models, design examples, and extensively documented case studies. In addition, simple calculations and spreadsheet examples are utilized and highlighted in numerous places in the sixth edition, which contains over 80 worked examples, over 220 homework problems, and 13 major case studies.

The Internet offers many sources for access to regional data with minimal cost and effort. Among those, U.S. Geological Survey, National Weather Service, National Resources Conservation Service, U.S. Army Corps of Engineers, and other state and local agencies should be emphasized for students as likely sources of regional hydrologic data. The textbook website (hydrology.rice.edu) contains a complete set of PPT slides for classroom instruction, along with datasets, spreadsheets, modeling hints, tutorials, and other resources. Dr. Bedient maintains the website that is available to any instructor and student in the course at no charge. These resources are designed to improve the teaching of a hydrology course at either the undergraduate or graduate level. In addition, an updated Solutions Manual is available for instructors. For more details on available resources, see the textbook web site—hydrology.rice.edu—.
ACKNOWLEDGMENTS

The current edition of the textbook was developed over a period of 35 years, beginning in 1982, from original course notes in a class in Hydrology and Watershed Analysis at Rice University. During the many years of interaction with colleagues and students, the book evolved into its present form with emphasis on simple examples, clear explanations, and modern computational methods. The sixth edition includes updated text, homework, and examples in all chapters, and new chapters written by a number of amazing colleagues. I am of course indebted to my co-authors, Dr. Wayne Huber and Dr. Baxter Vieux for their invaluable contributions over the years and the new updates in Chapters 3, 6, and 11. I am also indebted to Dr. Wesley Highfield and Dr. Antonia Sebastian for a newly revised Chapter 10, Dr. Antonia Sebastian and Avi Gori for a newly revised Chapter 12, and Dr. Nick Fang, Dr. Andrew Juan, and Catherine Nikkel for a newly revised Chapter 13. Significant example updates are included in Chapter 7 (Dr. Jacob Torres) and Chapter 8 (Dr. Phil DeBlanc). We also thank Dr. Jeri Stedinger of Cornell University for his highly informed help in updating the Bulletin 17B flood frequency analysis procedures described in Chapter 3.

The City of Austin Watershed Protection Department led and funded the project that was used as the SWMM5 Case Study in Chapter 6, Section 8. Geosyntec Consultants was the prime contractor and lead modeler, with assistance from Chan and Partners Engineering, Heather Venhaus, Linda Pechacek, ACR LLC, and Dr. Michael Barrett. Key staff at the City of Austin included Mike Kelly, Leila Gosselink, and Roger Glick.

We are particularly indebted to the following individuals for their careful review of the draft manuscript and for numerous suggestions and comments: Holly Stark, Senior Editor at Pearson, was instrumental in guiding the significant changes for this sixth edition; the authors thank all the professionals at Pearson for their efforts on our behalf, especially Scott Disanno, Carole Snyder, and Preethi Sundar.

A successful textbook always represents a team effort, and the support team at Rice University has been excellent in their organization and great attention to detail. Special thanks are due to Megan Goings and Rik Hovinga at Rice University for their technical skills in organizing and reviewing text and figures, permissions, and for providing valuable input to examples and homework problems. We would also like to thank Rice University students Matt Garcia, Alison Archibal, Bob Zhang, and Toby Li who assisted greatly in developing new problems, solving examples, and developing and checking new homework solutions for the sixth edition.

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