Water Resources and Hydraulics

This exciting new textbook introduces the concepts and tools essential for upper-level undergraduate study in water resources and hydraulics. Tailored specifically to fit the length of a typical one-semester course, it will prove a valuable resource to students in civil engineering, water resources engineering, and environmental engineering. It will also serve as a reference textbook for researchers, practicing water engineers, consultants, and managers. The book facilitates students' understanding of both hydrologic analysis and hydraulic design. Example problems are carefully selected and solved clearly in a step-by-step manner, allowing students to follow along and gain mastery of relevant principles and concepts. These examples are comparable in terms of difficulty level and content with the end-of-chapter student exercises, so students will become well equipped to handle relevant problems on their own. Physical phenomena are visualized in engaging photos, annotated equations, graphical illustrations, flowcharts, and tables.

Xixi Wang is a professor in the Civil and Environmental Engineering Department at Old Dominion University, where he is Director of the Hydraulics/Water Resources Engineering Laboratory. He has extensive teaching and research experience in hydrology, hydraulics, and water resources. He has published in many high-quality journals and has served as an Editor-in-Chief of the *International Journal of Water Sciences*, and associate editor for the *Journal of Spatial Hydrology*, *Transactions of the American Society of Agricultural and Biological Engineers*, and *Applied Engineering in Agriculture.* In 2018, he won the Most Inspiring Faculty Award at Old Dominion University, and was awarded the National First Award of Science and Technology Research Excellent Achievement in a Higher Institution of China by the Chinese Education Ministry.

"This is an excellent textbook for surface water and groundwater hydraulics, as well as water resources engineering. The systematic and detailed presentation of design examples and the high-quality problem sets at the end of each chapter are major strengths and should help the student grasp complicated concepts and design procedures."

Krishnanand Maillacheruvu, Bradley University

"The book presents a broad range of fundamental topics necessary for design of water resources systems, and illustrates their utility with practical modern-day applications . . . The examples are well laid out with detailed explanations, which makes understanding of the material easy. The appendices provide a quick introduction to advanced spreadsheet analysis and mathematical models, which are essential for modern-day engineering practice."

Venkatesh Uddameri, Texas Tech University

"This book is a much needed update to classical textbooks on water resources. Students often clamor for more examples and this text does an outstanding job of presenting numerous example problems, and it even integrates examples of how to use common engineering software to help solve these problems. I also appreciate the simple use of color to clarify the meaning of each variable in equations . . . designed with specific suggestions for use that will make the book easy to implement in my own course. Overall, this is a much needed, easy to use, and modern undergraduate textbook."

Bradley Striebig, James Madison University

"The textbook *Water Resources and Hydraulics* integrates hydrologic and hydraulic principles. Numerous solved examples within the text illustrate basic concepts and procedures, and the end-of-chapter problems are very instructive for students and course instructors. This will be a very useful textbook for students interested in water resources."

Vijay P. Singh, Texas A&M University

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Preface

Water Resources and Hydraulics is written for an upper-level, one-semester course for students majoring in civil, environmental, hydraulic, and/or water resources engineering. Ideally readers will have had previous instruction on hydromechanics or fluid mechanics, but may or may not have exposure to hydrology. This textbook can also be used as a continuing education or self-study reference for practical engineers, consultants, and water resources managers.

This textbook presents fundamental materials, practical examples, and problems in depth to maximize the teaching–learning results. It is devised for students to efficiently gain an elemental understanding of the fundamentals of hydrologic analysis (e.g., estimation of design storm, runoff volume, and peak discharge) and hydraulic design (e.g., selection of pump and turbine; sizing of channel, conduit, bridge opening, and culvert; and computation of water surface profile). Furthermore, this textbook covers the basics of groundwater hydraulics and unsteady-state flow.

Unlike most of the competing books that are currently available, this textbook does not attempt to present the contents that should be covered in other subject-specific books on hydrology, hydromechanics, fluid mechanics, sediment and pollutant transport, and hydrologic and hydraulic modeling. Those detailed subject matters can be redundant, diluting and distracting students from the topics that are imperative for building a basic capability of hydrologic analysis and hydraulic design. The primary mission of a *water resources and hydraulics* class is ultimately to impart the necessary topics for building said capability. Though such a class may have a different name, such as Water Resources Engineering, Hydraulic Engineering, Water Resources and Hydraulics, or Applied Hydrologic Design, depending on the university and/or college, the class is usually taught for one semester as a required junior- and/or senior-level course for all civil and environmental engineering undergraduate students. This textbook intends to best serve the above mission by overcoming the weaknesses of the competing books.

Xixi Wang

This textbook is unique for four reasons. First, its topics are carefully selected so that the cores of hydrologic and hydraulic engineering are introduced with sufficient detail for students to gain and retain knowledge in these fundamentals. Second, example problems, which are carefully selected and solved step by step, clearly demonstrate the relevant principles, concepts, and calculations. They are also comparable, in terms of difficulty level and content, with corresponding end-of-chapter problems. Third, annotated equations, flowcharts, graphical illustrations, monographs, photos, and tables are used to visualize the physical phenomena and facilitate understanding of the related principles. Finally, this textbook provides sufficient detail for all selected topics and can operate as a one-stop information source. Therefore, the instructors who use this textbook will not need additional reference books.

Acknowledgments

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How to Use This Textbook

This textbook is organized into ten chapters and contains five appendixes. **Chapter 1** presents an overview of the practices and principles of water resources engineering. **Chapter 2** reviews the basics of fluid mechanics, which are needed background for subsequent chapters. **Chapter 3** discusses hydrologic processes and analysis methods related to design and management of water resources engineering structures. **Chapter 4** discusses methods for formulating synthetic hydroclimatic extremes for hydrologic engineering design purposes through statistical analysis of observed data on rainfall and streamflow and conceptual empirical formulas. **Chapter 5** discusses the characteristics and selection of two commonly used hydraulic machines, namely pumps and turbines, from a hydraulic engineering perspective. **Chapter 6** describes water surface profile classification and computation, flow measuring, and channel design. **Chapter 7** introduces the application of the continuity equation and/or the energy equation in formulating the governing equations for a single pipe, a pipeline, and a pipe network. **Chapter 8** introduces the principles of hydraulics as they relate to common structures, including culverts, bridges, risers, storm sewers, spillways, and stilling basins. **Chapter 9** discusses the basics of groundwater hydraulics. **Chapter 10** discusses three types of unsteady-state flows. The appendixes present the relevant constants, unit conversion factors, basic calculus, and commonly used hydrology and hydraulic models. There is also a demonstration on how to use Microsoft Excel® Solver.

This textbook is written with a presumption that students already have the prerequisites of calculus, physics, dynamics, fluid mechanics, and probability and statistics. For a standard semester of 18 weeks with classes of three hours per week, the times can be allocated to the chapters in reference to Table 1. The first test covers the material in Chapter 1 through 4, and the second test covers the material in Chapter 5 through 7. The final exam can either be comprehensive or cover only the material in the last three chapters. For schools with a separate hydrology course, the times allocated to Chapter 2 through 4 may be reduced by 0.5 to 1.0 hours, which can be reallocated to the chapters in terms of the instructor's judgement. In addition, if groundwater hydraulics is taught in an independent required course, the 1.5 hours for Chapter 9 can be reallocated to other chapters. Furthermore, some instructors may emphasize steady-state flow, so the 1.5 hours for Chapter 10 can also be reallocated to other chapters. The possible time allocations for these different class setups are presented in Tables 2 through 4.

Table 1 The suggested time allocations for a normal course setup.

Allotted weeks	Hours	Class content
1.0	3.0	Chapter 1 and Appendix III
1.5	4.5	Chapter 2
1.5	4.5	Chapter 3
1.5	4.5	Chapter 4
0.5	**1.5**	**First test**
2.0	6.0	Chapter 5
2.0	6.0	Chapter 6
1.5	4.5	Chapter 7
0.5	**1.5**	**Second test**
2.0	6.0	Chapter 8
1.5	4.5	Chapter 9
1.5	4.5	Chapter 10 and Appendix IV
1.0	**3.0**	**Final exam**

Table 2 Suggested time allocations with a prerequisite of hydrology.

Allotted weeks	Hours	Class content
1.0	3.0	Chapter 1 and Appendix III
1.5	4.5	Chapter 2
1.0	3.0	Chapter 3
1.0	3.0	Chapter 4
0.5	**1.5**	**First test**
2.0	6.0	Chapter 5
2.5	7.5	Chapter 6
2.0	6.0	Chapter 7
0.5	**1.5**	**Second test**
2.0	6.0	Chapter 8
1.5	4.5	Chapter 9
1.5	4.5	Chapter 10 and Appendix IV
1.0	**3.0**	**Final exam**

Table 3 Suggested time allocations with a separate groundwater class.

Allotted weeks	Hours	Class content
1.0	3.0	Chapter 1 and Appendix III
1.5	4.5	Chapter 2
1.5	4.5	Chapter 3
1.5	4.5	Chapter 4
0.5	**1.5**	**First test**
2.0	6.0	Chapter 5

Allotted weeks	Hours	Class content
2.5	7.5	Chapter 6
2.0	6.0	Chapter 7
0.5	**1.5**	**Second test**
2.5	7.5	Chapter 8
1.5	4.5	Chapter 10 and Appendix IV
1.0	**3.0**	**Final exam**

Table 4 Suggested time allocations with steady-state flow only.

Allotted weeks	Hours	Class content
1.0	3.0	Chapter 1 and Appendix III
1.5	4.5	Chapter 2
2.0	6.0	Chapter 3
2.0	6.0	Chapter 4
0.5	**1.5**	**First test**
2.0	6.0	Chapter 5
2.5	7.5	Chapter 6
2.0	6.0	Chapter 7
0.5	**1.5**	**Second test**
2.5	7.5	Chapter 8
1.5	4.5	Chapter 9
1.0	**3.0**	**Final exam**

Each chapter has a number of problems closely related to its content and worked examples. Besides a complete solution manual and the relevant Excel spreadsheets, the answers to selected problems are provided online as a stand-alone supplementary sheet. The instructor may assign these and/or other problems for homework and decide whether or not to make the answers available for students before the homework is due. Depending on the difficulty level and number of assigned problems, each homework may take one or two weeks. It is ideal to assign a problem halfway through lecturing on a topic to maximize teaching effectiveness and provide students with quick feedback on their comprehension. In addition, the instructor may use some of the problems as out-of-class exercises or in-class quizzes. Finally, the instructor may relate the problems with the real world to stimulate students' learning interests.