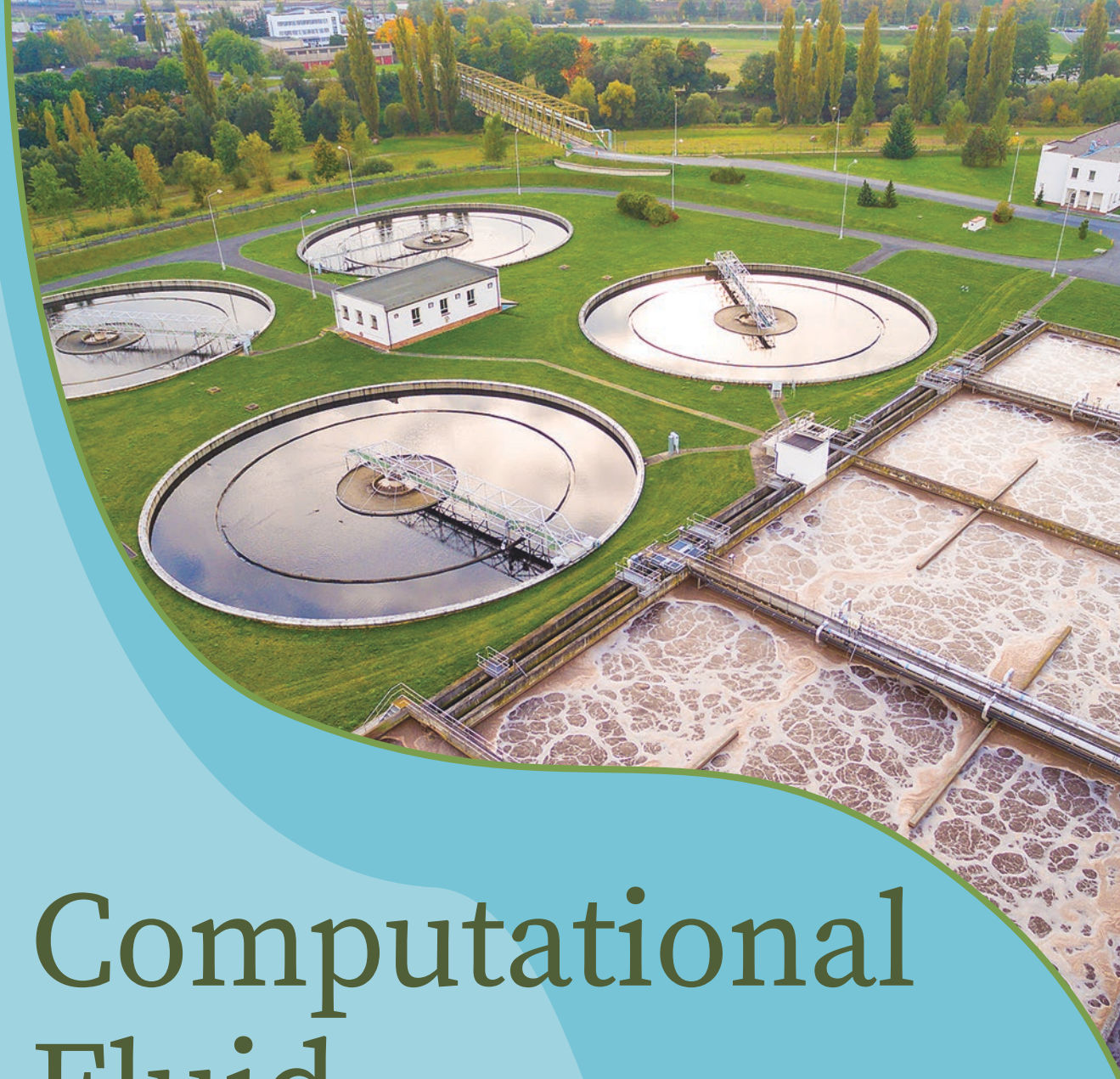

Computational Fluid Dynamics

Applications in Water, Wastewater, and Stormwater Treatment

Computational Fluid Dynamics
Task Committee

EDITED BY

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Applications in Water, Wastewater, and Stormwater Treatment

EWRI Computational Fluid Dynamics Task Committee

Edited by
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Preface

Background and History

Computational fluid dynamics (CFD) has proven to be a valuable and sometimes indispensable tool for designing new and retrofitting existing water and wastewater systems. The availability of ever-increasing computing power further spurs the adoption of CFD in engineering practice and academic research for water infrastructure. However, traditional design methods, which heavily depend on empirical formulas and scaled physical models, still prevail in most engineering projects. CFD models are mostly used as a side exercise to complement traditional design methods, mostly because of the culture of relying on proven methods in a traditional field, such as water and wastewater treatment. This situation occurs also because of the lack of proper training of engineers, at school and on the job alike, thus resulting in fewer CFD experts in the water and wastewater community than in other fields, such as mechanical engineering and the aerospace industry. Therefore, the purpose of this book, which we refer to as a primer, is to introduce CFD to the water and wastewater engineering community and to provide a general overview of what it is and how it can be used.

Promoting CFD in the water and wastewater treatment community, as in many other traditional fields, is a challenge. I have been teaching water resources engineering and environmental hydraulics at several institutions for the past 10 years, and I have observed that typical civil and environmental engineering programs do not include advanced computational fluid modeling in their undergraduate curricula. At most, students are only exposed to basic numerical techniques, such as the finite difference method. CFD courses in civil and environmental graduate programs are also rare. Even after school, engineers do not have many opportunities to find training on CFD since there are not many training and educational opportunities available.

Despite the slow pace of the adoption of CFD in the water and wastewater industry, people are beginning to realize the value of such computational tools. CFD is being used more often in practice; therefore, there is a need for training in and promotion of CFD in the water community. With this backdrop, a group of researchers and practitioners conceived the idea of forming a technical committee within ASCE's Environmental and Water Resources Institute. One of the goals of the committee was to produce this book to be used by water engineers and designers.

The content and the level of detail in the primer went through several iterations of revisions, based on input from members of the technical committee and others who participated in several workshops. Workshops were held

concurrently at two EWRI World Congress conferences and one at ASCE headquarters. The committee reached the consensus that the primer, as its name implies, should include general procedures for conducting flow, transport, and reaction simulations using CFD and specific examples in water and wastewater treatment applications. Considering the training that most water engineers acquired in school, this book assumes prior knowledge of numerical analysis and computational methods as a minimum. On the other hand, sufficient details and references are included to facilitate the proper use of CFD.

A signature characteristic of this primer is that examples are provided, including the input files and part of the results. Engineers can follow the detailed examples and ultimately be able to adapt one or more of these examples to solve their own problems of interest. The original plan was to use open-source or public domain CFD codes exclusively for this book. The reason is obvious: Not everyone has access to commercial CFD software, and the fee for a license can be a heavy financial burden. However, during the development of this primer, committee members, especially those who did have commercial CFD software licenses and have used them in their work, contributed their cases as examples. As a result, the application examples in this book use a mix of open-source and commercial software.

The committee hopes that this primer will grow interest and build a community. Over time, we anticipate that CFD will gain in popularity and acceptance for water and wastewater treatment design.

About the Task Committee

This ASCE EWRI Task Committee was formed in 2015 with the name Computational Fluid Dynamics Applications in Water and Wastewater Treatment under the Water Supply, Treatment and Distribution Engineering Committee and the Water, Wastewater, and Stormwater Council. Jie Zhang, a researcher at South Florida University at the time, was the chair from the beginning to 2017. Then, I became the chair in 2017. We have about 20 active members who have participated in various technical activities since the inauguration of the committee, including regular online meetings, workshops, and training courses. The composition of the committee is almost half from industry and half from academia. Many of the members directly contributed to the writing of chapters of this book or served as technical reviewers. As in many other ASCE committees, almost all members volunteered their personal time to this cause because of their passion and dedication to their profession.

This task committee aims to provide civil and environmental engineers guidance on when and how to use computational fluid dynamics in solving fluids-related problems for water and wastewater treatment design. Two objectives were proposed: (1) to develop a primer on computational fluid dynamics (CFD) applications in water and wastewater treatment, and (2) to promote CFD tools in the water and wastewater treatment community by disseminating the primer and organizing workshops and webinars. With the publication of this primer, the first objective has been met. The second objective has partially been met, as evidenced by the past workshops and planned training courses and webinars.

The following is a brief account of the committee work since the beginning, which led to the publication of this book and beyond.

- *October 2015–January 2016*: The committee identified water and wastewater treatment technologies for which CFD has been applied or has the potential to be applied through literature review, field practitioner surveys, and task committee discussions. A tentative outline of the primer was developed.
- *February 2016–May 2016*: Subtask committees were established, and members were assigned based on their interests and expertise. Subcommittee leaders were also appointed. Furthermore, a technical session on CFD applications in water and wastewater engineering was organized at the 2016 EWRI World Congress. During the congress, feedback was collected from other EWRI attendees not on our task committee.
- *June 2016–December 2016*: Regular online meetings were held involving all task committee members. Committee members communicated with engineers who have solved water and wastewater engineering problems using CFD tools. A draft primer was developed with case studies.
- *January 2017–May 2018*: The draft of the primer was submitted to the Water Supply, Treatment and Distribution Engineering Committee and the Water, Wastewater, and Stormwater Council for reviews. The primer was finalized and submitted to ASCE for publication. A workshop and panel discussion were organized at the 2017 EWRI World Congress to promote the primer and the use of CFD tools in water and wastewater treatment design. The task committee also discussed the possibility of extending the primer to a manual of practice.

The task committee has disseminated the primer by publishing a summary version through the ASCE website and by organizing webinars. The full version of the primer is available through the Civil Engineering Database of ASCE. In the future, depending on the feedback from the water and wastewater community, the task committee may further develop a manual of practice on this topic.

Organization of This Book

The book is organized into five parts, each of which has several chapters written by individual committee members. The following is a short summary of each part.

- **Part 1: Physical, Chemical, and Biological Processes in Water, Wastewater, and Stormwater Treatment.** This part provides a succinct overview of the processes occurring at most treatment facilities. These processes, ranging from physical transport to chemical and biological reactions, and the corresponding mathematical models, constitute the technical backbone of this primer. Readers are expected to know some general concepts of these treatment processes and can connect the mathematical equations with the underlying physics, chemistry, and biology.
- **Part 2: Fundamentals of Computational Fluid Dynamics.** CFD itself is an area with rich content covering fluid dynamics, numerical methods,

turbulence and modeling, software engineering, and parallel computation. The chapters in this part provide a brief introduction to the background, basic processes and steps, and analysis involved in typical CFD studies.

- **Part 3: Water Treatment Technologies and CFD Application Case Studies.** Chapters covering different water treatment processes, that is, aeration, sedimentation, ozone disinfection, pumping, and flow distribution, present example applications frequently encountered in water treatment. These processes may also be used in wastewater and stormwater treatment.
- **Part 4: Wastewater Treatment Technologies and CFD Application Case Studies.** Chapters covering typical processes in wastewater treatment, that is, activated sludge tanks, water stabilization ponds, algae raceway ponds, and UV disinfection, showcase how CFD can be used to evaluate wastewater treatment efficiency.
- **Part 5: Stormwater Treatment Technologies and CFD Application Case Studies.** Chapters were included to cover collection, filtration, particle separation, and geysering (transient) processes to promote efficiency and safety of stormwater collection, treatment, usage, and disposal.

Parts 1 and 2 are the foundations for both the treatment process and CFD; Parts 3, 4, and 5 demonstrate how CFD can be used to simulate various aspects of water, wastewater, and stormwater treatment with the presentation of case studies. The reader may review the chapters in the presented order for a more comprehensive view of the CFD field or may select chapters to review specific topics of interest.

The companion cases for Parts 3, 4, and 5 (Chapters 9 to 23) can be downloaded from https://doi.org/10.4211/hs.344350caa2e341f5a8a9eb33cbed3f78

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