

Groundwater for the 21st Century

For
William B. Hall

Groundwater for the 21st Century

A Primer for Citizens of Planet Earth

by

John A. Conners, Ph.D.

The McDonald & Woodward Publishing Company
Granville, Ohio

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GROUNDWATER FOR THE 21ST CENTURY
A PRIMER FOR CITIZENS OF PLANET EARTH

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P Preface

Why Water?

Why learn about water? For one thing, water is fascinating. What child doesn't enjoy playing in puddles and streams? Water is many things: beautiful and comforting, strange and mysterious, terrifying and destructive. Above all, it is necessary. Water is our most important natural resource. Too much water can be disastrous; too little will mean the end of life. Without water, no life as we know it can exist — on Earth or anywhere else. Despite this, water resources have been abused, ignored, wasted, taken for granted, contaminated, and depleted to such an extent that billions of people are presently threatened with water scarcity, water-borne diseases, floods, and other water-associated problems.

The water upon which our survival depends is fresh liquid water, and some 99% of that water exists beneath the land's surface. It is groundwater! The main reason for learning about groundwater, then, is its vital importance as an essential resource for humankind — indeed, for all life on Earth — and the rapidly encroaching necessity to manage and conserve fresh water far more effectively than we have ever done before.

On this small, isolated, and overpopulated planet, the greener pastures of yesteryear no longer exist to support a continuation of humanity's material growth and greed. At this moment, millions are suffering, and many thousands will die within the next 24 hours simply because they lack clean, fresh water. Over the span of a year, water-related human deaths number in the millions. Most are children, over 4,000 of them every day, and their afflictions and deaths are unnecessary. Enough water, food, and other resources still exist to sustain our current population. It is not water *per se* which is lacking. It is the knowledge, priorities, actions, and morality of humans which require improvement. If solutions are to be found, unprecedented suffering averted, and the prospect for a healthy, hopeful future preserved, humankind needs to understand and utilize this resource far better than it has done in the past.

All too often, we tend to deny that which we find unpleasant or threatening, especially if it produces feelings of discomfort or guilt, may require extra effort from us, or yields an economic disadvantage — that is, if it costs money, reduces profits, or requires a redistribution of wealth and resources. Our nature is to grasp at simplified, poorly conceived quick fixes which rarely succeed. Lasting solutions will require dramatic changes in the standard economic and political approaches, not to mention a rarely achieved degree of honesty and humility.

And time is not on our side. Even for those living in wealthy nations, the time to act intelligently is growing frighteningly short.

Why This Book?

Groundwater for the 21st Century is a broad, flexible resource that will be of value to a wide audience of readers. This is not a textbook, it does not have pages filled with differential equations or other expressions demanding expertise in more advanced sciences or engineering. Neither is it a “popular science” book, filled with human interest stories and local investigations. Rather, it is a volume that aims to provide a basic understanding of groundwater science and resources, and the use of those resources by humans, in a manner which is accessible to all — and particularly those who are not specialists.

When teaching my first course focusing on water some 30 years ago, I had a difficult time finding publications suitable for use in such a class. Hydrogeology and groundwater textbooks required an understanding of higher level math and assumed considerable knowledge of engineering or geology, none of which my students possessed. More popular books about water focused on environmental and resource concerns, including many detailed stories about specific places and their water issues. People can relate to these stories and how water problems have affected individuals, their families, and communities. Well-told stories often make a much stronger impression upon an audience than does cold, hard science. Many excellent books and other publications about water resources are available, and several of these are listed in our References.

Nothing is wrong with either the hard-core science books or the more accessible popular publications dealing with water. Both are necessary. The technical science books, however, are often beyond the reach of most readers while the more popular books tend to skim over or completely avoid the basic science of water, especially groundwater. In addition, most students — and the general public — today are less well

prepared in science and math than they were 30 years ago, this at a time when pressure on maintaining and managing water resources has never been greater and continues to increase. Hopefully, this book will help to fill the yawning gap between the advanced texts and the popular science publications that are now available. Increasingly, people need to know the basic science of groundwater, how that resource is being used, and the implications of that use — and to have the confidence in their knowledge to use it. In so many cases, past and present, untold cost and suffering could have been avoided, if only more knowledge of the critical groundwater resource had been available and utilized.

As water issues become ever more acute, large numbers of people of diverse backgrounds find themselves needing to understand, and make decisions involving, complex water issues. The values of water knowledge are apparent to those in scientific and engineering fields which involve water. But just as important is the fact that countless others whose education and experience may not have included a strong science component also need to cope with water issues. Attorneys, businessmen, agricultural experts, ecologists, urban planners, politicians, economists, geographers, conservationists, foresters, engineers, and many others, including millions of average citizens and vast segments of global society as a whole, can benefit from a basic understanding of water. Virtually every government in the world is or soon will be facing serious water problems. The major limiting factor in agriculture's ability to feed the world's growing population is water supply. Many plans to address the growing energy crisis will be limited by the large amounts of water needed to retrieve and process basic fuels and raw materials and/or the high cost of obtaining water. Not surprisingly, water-related litigation is growing by leaps and bounds.

Groundwater for the 21st Century is intended for use by citizens who have diverse interests in and concerns about fresh water and its fundamental influence on their lives. In it, I have attempted to cover basic scientific and hydrogeologic principles in a way that will be understandable to individuals who may lack a strong background in geology, engineering, math, chemistry, or science in general. Introductions to some very basic science are included to provide a context within which the genuine understanding of concepts, interrelationships, applications, and implications relevant to groundwater might be realized. Expanded coverage of the science, use, and abuse of groundwater follows. Numerous diagrams provide clear graphic illustrations of basic groundwater patterns and behavior.

Regarding terminology, the groundwater field, like all sciences, is awash with both a vocabulary of precision and jargon. If one wishes to learn about, and communicate in, this vitally important field, s/he will need to have some familiarity with the terminology. While I have attempted to limit use of highly technical terms in this book, many terms are so widely used and important that I felt it necessary to introduce them. It is also beneficial to point out widely used equivalent terms along with inconsistencies in terminology use. When a term is first encountered and defined, or is a key-word for the topic being presented, the word will be **boldfaced**.

Content

Focus on Subsurface Water

The primary purpose of this book is to provide an introduction to subsurface waters: their nature and distribution, their behavior, their interactions with the surface environment, their value as a resource, and the major issues associated with groundwater resources today.

Qualitative and Quantitative Aspects

Although the emphasis here is on attaining a qualitative understanding of the subject matter, the nature of water science requires some quantitative treatment at times. For these sections, math through elementary algebra will be needed. Where appropriate, sample problems are provided in the text to illustrate the use of various simple but important formulae or equations.

Units and Measures

Scientists prefer the **metric** or **SI** (*Système International d'Unités; System Internationale*) **system** of units due to its ease of use and worldwide usage. Unfortunately the United States clings to the more cumbersome **English system**. Familiarity with both systems is a valuable asset and both systems are employed in this book. Both units are not used in every case because an abundance of parentheses tends to impair readability. To improve readability and save space, common abbreviations are frequently used in the text. A key to the abbreviations, acronyms, prefixes, and symbols used in this book is provided in Appendix A. Units and conversion factors important in water studies are given in Appendix B.

Current Water Resource Issues

For perspective, examples of groundwater resource issues are noted throughout the text and overviews of important water topics and problems are provided in chapters 12, 13, and 14.

Thumbnail Sketches of Each Chapter

Chapter 1: Introduction. The stage is set with a brief perspective on vital water-related issues, and a review of water itself and its importance. Following a brief review of very basic chemistry and physics, the characteristics, origin, types, and distribution of water are examined in some detail.

Chapter 2: Geology. It is impossible to understand the nature and behavior of subsurface water without some knowledge of geology. This chapter provides a minimalist introduction to the geologic features and principles most important to the water sciences.

Chapter 3: The Hydrologic Cycle. This chapter reviews the major steps and processes involved in the constant recycling of water throughout Earth's environment. The hydrologic aspects of the atmosphere, vegetation, terrain, soils, climate, and related factors are discussed.

Chapter 4: Surface Water. Water which reaches Earth's land surface from the atmosphere is the source of nearly all subsurface water. This chapter focuses upon the intimate relationship between water running off or sitting upon the land and water seeping into or out of the outer part of the solid Earth.

Chapter 5: Vadose Water. This chapter describes subsurface water in the unsaturated zone — that is, the types and behavior of water occurring between Earth's surface and “true groundwater.”

Chapter 6: Phreatic Water. Here we describe the behavior of subsurface water in the saturated zone: types of water, how it moves, fluctuations in the water table, natural and human influences, various types of groundwater flow regimes, and the basic methods of determining groundwater movement, flow direction, and magnitude.

Chapter 7: Wells. Wells are critical components in the study of groundwater. Wells provide water for our use and enable us to determine groundwater behavior and quality. Many types and uses of wells are reviewed.

Chapter 8: Aquifers and Hydrogeologic Regions. Aquifers are the primary sources of usable groundwater supplies. Basic aquifer types, properties, and examples are examined, followed by a review of the major hydrogeologic environments of Earth.

Chapter 9: Groundwater Chemistry. What's in water besides water? The natural chemicals found in groundwater and the chemical reactions which influence them are examined.

Chapter 10: Groundwater Pollution. This chapter describes the major groundwater pollutants and their sources, impacts, transport, and fate.

Chapter 11: Applied Hydrogeology. This chapter discusses the practical skills and activities required of a hydrogeologist, including water sampling, site characterizations, groundwater remediation, modeling, ethics, and related topics.

Chapters 12: Contemporary Groundwater Supply Issues. Water use and supply, the impacts of groundwater depletion, legal and ethical considerations, conflicts over water, and climate change and its impacts are addressed in this chapter.

Chapter 13: Facing the Challenge. The focus here is on corrective actions, including conservation and management of groundwater resources and locating alternate sources of water.

Chapter 14: Perspectives on Tomorrow. This concluding chapter provides an overview of the global and regional impacts of diminishing water resources as well as the implications of, and possible solutions to, current megascale problems.

Appendixes. Three appendixes provide definitions of abbreviations, acronyms, prefixes, and symbols used throughout the book; conversion tables for numerous quantitative values and systems useful in the science and use of groundwater; and an annotated list of maximum contaminant levels for drinking water in the United States.

References. The references listed at the back of this book include those cited in the text and other relevant publications. A separate list of periodicals, organizations, and other important sources of information is also provided. All references cited in the text have been assigned a unique number and are identified in the text by their corresponding number placed within brackets, as, for example, [132].

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