Unsaturated Zone Hydrology for Scientists and Engineers

James A. Tindall, Ph.D.

United States Geological Survey, National Research Program,
Unsaturated Zone Field Studies;
Department of Environmental Science, University of Colorado at Denver

James R. Kunkel, Ph.D., P.E.

Knight Piésold, LLC, Denver, Colorado;
Department of Geology and Geological Engineering, Colorado School of Mines

with

Dean E. Anderson, Ph.D.

United States Geological Survey, National Research Program,
Unsaturated Zone Field Studies

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Preface

Unsaturated zone hydrology has become a vital part of the environmental sciences and of engineering, especially in relation to the characterization, modeling, cleanup, and monitoring of residual solid and liquid storage and disposal. Current and future trends in the environmental sciences and engineering (including multidisciplinary investigations, increasing technological capabilities, more restrictive regulations, and increased hazards to the environment imposed by a growing population), and the viability of employment as scientists, technicians, consultants, environmental engineers, regulators, and so on, in the area of unsaturated zone hydrology, requires a more thorough working knowledge for this field of science. Some universities teach related material in courses on soil physics and agricultural engineering. These courses, however, often do not encompass many environmental fields, and do not always include chemical properties of soils, modeling, monitoring, and contaminant transport. All of these topics, as well as the traditional soil physics topics, are extremely important in the environmental sciences, engineering consulting, and regulatory oversight.

During the past seven years, at both the University of Colorado and Colorado School of Mines, we have taught many students from a wide variety of backgrounds and skill levels in our unsaturated zone hydrology classes. Typical prerequisite classes have not prepared them well for investigating phenomena in the unsaturated zone. Because a knowledge of the unsaturated zone is multidisciplinary, we have been urged by our students to write a book of this nature—beginning with basic physical properties and the behavior of clays, and continuing to include contaminant transport and other parameters such as spatial variability, scaling, and fractals in the earth sciences.

This text was written in response to our students' concerns. It is designed for upper-level undergraduate and beginning graduate students in the fields of environmental science, geology, hydrology, engineering, soil science, soil mechanics, soil physics, and agricultural engineering. While it is possible to cover most of this text in a single semester, some sections are quite lengthy—and perhaps more detailed than necessary. Instructor discretion is required in shaping a meaningful unsaturated zone course, to meet specific objectives. However, the more lengthy and advanced sections can be used as a reference. We have used this book in both basic unsaturated zone hydrology courses at a more applied level, and advanced courses. The primary objective of the basic course is to teach the major processes that occur in the unsaturated zone, and to prepare students to design and install instruments (such as thermocouples, lysimeters, dataloggers, and so on) in order to collect and analyze data under unsaturated zone conditions. In addition to developing greater expertise in devising an unsaturated zone study, the advanced course focuses on modeling the collective data on a computer and making predictions, through monitoring and other risk-assessment techniques, concerning times of transport of a contaminant to ground water and potential hazards to the environment. For either course, the student should have a good mathematics background (including at least two semesters of calculus and, preferably, partial differential equations). In addition to mathematics, a study of the unsaturated zone requires an understanding of many disciplines; thus, it is helpful if the student has studied geology/hydrology/hydrogeology, ground water, soil science, physics, and chemistry at the college freshman or sophomore level.

Chapter 1 defines the unsaturated (vadose) zone, describes current environmental problems in this area, and gives a brief history of unsaturated zone hydrology. Chapter 2 introduces physical properties of soils, and chapter 3 concentrates on the behavior of clay–water systems.

Chapters 4 and 5 define the energy, thermodynamic, and chemical states and properties of soil-water systems. These chapters define the structure of water, the theory of potential as applied to the soil-water system, hysteresis, and organic and inorganic reactions in the soil-water system.

Chapters 6 through 8 present the principles of water flow in soil, water flow in saturated soils, and water flow in unsaturated soils, respectively, from a theoretical perspective. Chapter 9 (written by Dean Anderson) presents the theory of gaseous transport in soil systems.

Chapters 10 through 15 use the definitions, concepts, and theories from the previous nine chapters to investigate applied modeling of fluid movement and contaminant transport. Modeling concentrates on analytical solutions that are seldom presented in advanced texts, because we believe that analytical solutions are generally more available to the prospective student, and also more easily understood. However, a list of numerical unsaturated zone models is presented, along with references related to each. Chapter 16 is a unique exploration of fractals in soil physical properties, and presents a detailed discussion of soil spatial variabilitiy and water movement using fractals.

The text has been written primarily with the student in mind. Throughout the chapters, questions are given at the end of sections when we felt they were needed. These questions are answered completely at the end of each chapter. We did this for two reasons: completing work at the end of each section reinforces the material learned; and seeing the answer to the question increases the students' confidence in their ability to perform the work. Some instructors may feel that we are pampering the students with the complete answer, however; to offset this, and for the instructors' benefit, additional questions are asked at the end of each chapter. Answers to these questions will be found only in an instructor's solutions manual available from the publisher. In certain chapters, sufficient worked examples are given so that the student should not need direct questions with their respective answers.

There are many references that could have been used for the various principles presented in the text. We have made no attempt to indicate the first or primary author of a particular subject, nor to give the subject a complete citation. In some instances, where there has been little significant change in a specific area, we have chosen original references that date back many years; but we have also chosen those references that we believe will be of most value to the student, will represent the most important point of view, or will be most accessible.

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We sincerely hope that this text makes a practical contribution to the teaching of unsaturated zone hydrology, and fills an important gap in the hydrologic curriculum at the university level. We especially hope that, as a reference, it can be used by practicing environmental scientists and engineers in solving real-world problems. A companion text that covers the saturated zone, *Groundwater*, by R. Alan Freeze and John A. Cherry, is also available from Prentice Hall.

James A. Tindall
James R. Kunkel
Denver, Colorado