

Review of *Preferential Flow—Stokes Approach to Infiltration and Drainage*

Peter Germann. Geographica Bernensia 88. University of Bern, Institute of Geography, Bern, Switzerland. 2014. 199 pp. ISBN 978-3-90583534-2.

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This book encompasses Germann's multidecade pursuit of a more realistic representation of water flow in soils than generally accepted theory provides. It is an unusual example of a type of publication needed for making progress on a topic like preferential flow, where current understanding is limited, diverse directions of research are prominent, and the scientific community has not yet settled on an accepted approach.

The book's important contribution is the explication of a basis in theory and observation for important ideas that advance the understanding and quantification of preferential flow and that are not in mainstream unsaturated-flow textbooks. This material—concerning properties and principles associated with films, waves, and preferential flow through pores and spaces that are partially filled with water—needs serious consideration for possible addition to the basic toolbox of unsaturated zone scientists. Although most of these subjects are addressed in the many journal articles that Germann's research group has produced, laying out the full scheme in one book provides context and coherence important for understanding an approach that is innovative in multiple ways.

The first of the book's two parts covers fundamentals and theory. Early chapters review basic principles of unsaturated flow and fluid mechanics and describe Germann's concept of a water-content wave and its relation to film-flow dynamics. Initial discussions of the flow of water in films, and kinematic wave theory, though not new in themselves, are innovative in their particular application to preferential flow.

One of the book's highlights is an exploration of the effects of flow-path geometry. Various shapes and constraints (e.g., plane, tube, corner, free-surface) are evaluated with respect to empirical stability criteria. The geometries considered have been previously introduced in the fluid-flow literature, but the unified comparative treatment here gives insight into which effects really matter and which do not. The stability criteria, in terms of dimensionless numbers, put constraints on important flow parameters, such as characteristic film thicknesses and flow velocities. A related major contribution is the identification of a film thickness and contact area (often discussed as "contact length," in consideration of a cross-sectional plane rather than a volume), which can play vital roles in quantifying the physical processes of preferential flow.

Approaching the book's halfway point there is a frank and valuable discussion of Richards' equation and limitations of its usefulness for preferential flow. This material provides needed perspective on the relation of Germann's preferential flow approach to traditional unsaturated flow theory. Sometimes it is surprising how much and which particulars of Richards' interpretations, language, and notation are chosen for emphasis. An example is the assumption that the relation between capillary potential and water content is not hysteretic, of which I would have expected more criticism. I also would have liked to read

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more on the relation to the work of Buckingham that provides the fundamental basis for Richards' formulations.

Tests, examples, applications, and observational support of the theory comprise the second part of the book, with slightly more than half of the book's material. Case studies are generally introduced from the standpoint of the types of experimental inputs they employ and their role in supporting Germann's approach, a highly systematized mode of presentation. This part is organized by what might typically be called four different scales (in the sense of pore-scale, plot-scale, catchment-scale, etc.), which Germann refers to as four levels of complexity. From smallest to largest these are termed *flow path level*, *local level*, *profile level*, and *system level*. Here again, the concept of an effective thickness of a flowing film and the surface area per bulk volume that the film interacts with are central. Frequently in the examples, computations from observational evidence show the effective film thickness tends to be surprisingly small, and contact length per unit area (or contact area per unit volume), surprisingly large.

An unfortunate weakness of this book is its readability. The explanations require persistent attention to notational details, especially in equations and complex subscripts. There is frequent cross-referencing to equations and other material in earlier sections. These allusions are not only for optional or supplemental comparisons, but in many cases are essential for the reader's understanding of the material being explained. This type of approach economizes on words and pages, and minimizes restatements to a degree appropriate for a formalistic documentation, but does not make for an easily understood explication of creative ideas unfamiliar to some readers. It helps considerably that the use of symbols is consistent throughout the book, and that toward the end there is a five-page list of symbols, subscripts, and abbreviations, but it would be more understandable if there were more straightforward verbal explanation, relying more on descriptive words and phrases and less on notational representation.

Early in the book, Germann explains a preference for inductive reasoning in developing preferential flow theory, working from observed phenomena to general principles, as is appropriate for a subject where the processes are still poorly understood. This preference is apparent in his plenteous use of case studies and reliance on measured results. In the larger scope, however, the organization of the book obscures the inductive pattern. Part

1 presents theory without many examples, and Part 2 presents examples with less theoretical explication than would be desired. This organization also causes difficulty in a straight-through reading of the book, first in working through many pages of a fairly abstract theoretical realm with very few concrete examples, then in reading a series of experimental and observational case studies interpreted through concepts and equations that were presented a hundred or so pages earlier.

Throughout the book, I found myself having to adjust to terminology very different from what I would use myself. Some of this is just a matter of an author's personal preference, and some of it is just occasional carelessness. Some terms, however, may differ from what the reader has seen in other sources. Viscous flow is defined very narrowly, seemingly as a subset of viscous-flow possibilities in which capillarity is not important. Darcy's Law is considered not inclusive of unsaturated flow, even under steady flow conditions. Perhaps there is an implicit distinction here from what is often called the Darcy–Buckingham Law, which is not mentioned, as applying to the unsaturated case, with "Darcy's Law" being reserved for the saturated case. More explicit discussion of this matter would be welcome.

This book is suitable for readers with prior knowledge of the physics of fluids and flow in unsaturated porous media who desire to learn about far-reaching ideas that may come to form important components of a general unsaturated flow theory. It could serve as supplementary reading in an advanced course related to unsaturated flow. It would be suitable for discussion among research scientists and graduate students. It also, of course, serves as a reference on preferential flow and Germann's insightful approach, as well as a reference on kinematic waves in unsaturated media, film flow, and other topics, although I expect to use it mainly for the material it uniquely covers, as there are other books on fluids and transport phenomena that are easier reading.

Germann's book on preferential flow is a pioneering work relating material that deserves much greater prominence in the science of unsaturated flow. It provides many of the insights and inspirations that can be derived from Germann's earlier works. Though not as easy to read as it could be, this work is a welcome and refreshing contribution to the literature—not a textbook of widely accepted scientific constructs or a collection of research papers by multiple authors, but a coherent treatment of a broad topic of major importance.