Book review:

Seepage in Soils – Principles and Applications. Lakshmi N. Reddi. John Wiley & Sons, Inc., Hoboken,

NJ 07030. Hard cover, $110. ISBN 0-471-35616-6.

Zhi Wang
Department of Earth and Environmental Sciences
California State University, Fresno
2345 E. San Ramon Ave. M/S MH-24, Fresno, CA 93740.
Phone: 001(559)278-4427, Fax: 001(559)278-5980, Email: zwang@csufresno.edu

Seepage is a well established course of instruction in civil engineering, earth and environmental and soil and agricultural sciences. Students learn about seepage in several relevant courses such as hydrology, hydrogeology, hydraulics, fluid mechanics, irrigation and drainage, groundwater utilization, and soil physics. However, depending on the applications, the subject is treated in either very complicated or simple ways differing in the amount of mathematical derivations. To describe seepage principles in porous media, there exist textbooks like most introductory soils and geology books and more mathematical monographs like the "Dynamics of fluids in porous media" by Jacob Bear (1972).

This book by Lakshmi Reddi is an excellent blend of applications and mathematical derivations. As a professor and a professional engineer, the author reflects both in-depth analytical mathematics and relevant application issues and solutions. In presenting the principles and solutions, the author chooses to minimize the use of computer software and numerical models. High priority was given to available closed-form analytical solutions because these are more useful in providing insights into the problems.

In the introductory chapter 1, the author discusses many field applications of seepage problems and provides some historical background on pioneering theoreticians. As indicated therein, most seepage problems in civil engineering are related to the stability and safety of natural and man-made structures: slopes beside roads and important infrastructures, earth dams and retaining walls, foundation of large buildings, railway, highway, pavements and landfill facilities. Other applications are related to explorative and exploitative uses of soil and ground water resources: estimation of groundwater volume and discharge, design and construction of wells and pumping systems, and seepage in irrigation canals and

agricultural fields. The principles of seepage in porous media in general are also actively studied in petroleum and environmental engineering where such problems as multi-phase, multi-component flow through soils and fractured rocks are encountered and treated. Several analytical "forefathers" and "foremothers" of groundwater hydrology are featured in Chapter 1. The contribution of French engineer Henry Darcy (1803-1858) is introduced first. John Philip's paper "Desperately seeking Darcy in Dijon" (Soil Science Society of America Journal, 1995) was specifically cited, and the ethics of Darcy in the face of awards and money was also praised. Another French engineer, Arsene Dupuit (1804-1866), a year younger than Darcy, was recognized for making the well known Dupuit assumptions for the possible integration of the Darcy's equation applied to two-dimensional aquifer flow. The Dupuit assumptions were made in 1863. Then, Philip Forchheimer (1852-1933), from Vienna, used Darcy's law and Dupuit assumptions to derive the Laplace equation which enabled the drawing of flow nets around a water structure. Because of Forchheimer's excellent mathematical background, "his contribution accomplished more than those of all the other contemporaneous hydrologists of Europe combined," as commented (may not be accurate) by Karl Terzaghi, the "father" of soil mechanics, whose study led to a formal approach of incorporating seepage principles in the design of stable hydraulic structures. The author also mentioned Russia's "mother" of fluid mechanics, Pelagiea Polubarinova-Kochina (1899-1999). She used her mathematical skills in complex analysis and free boundary layer problems to solve difficult issues in groundwater movement. Her textbook *Theory of Motion of Ground Water* (1952) is a guidepost to researchers in the West. At the age of 100, Kochina was still contributing research papers to journals. Note that many Western scholars such as Milton Harr have expanded her work and familiarized the West with the Russia achievements. Among others, Harry Cedergren of the United States promoted the importance of seepage in civil engineering by characterizing the US pavements as the "world's longest bathtubs". It was a pity that other prominent pioneers and their analytical contributions to modern hydrogeology are not reflected in this book.

The core chapters of the book are divided into three groups. Chapters 2 to 6 present the principles and mathematical solutions. Chapters 7 and 8 deal with the design of filters and drainage layers for safe

dissipation of excess water and water pressures. Chapters 9 to 11 describe seepage materials and applications to specific infrastructure systems.

Chapter 2, Principles of Flow, is easily accessible. It starts from a short description of the well known Bernoulli's equation for energy conservation (which is usually covered extensively in hydraulics and fluid mechanics), then presents almost everything about the Darcy's equation and the methods of parameter estimation in both homogeneous and heterogeneous soils. Rarely seen from other sources is the detailed distribution of the elevation, pressure and total heads in typical soil columns for quick determination of flow directions. Chapter 3 provides detailed descriptions about Flow Nets. Based on the Laplace equation, flow nets can be applied to simple and complicated boundary conditions in both homogeneous and heterogeneous soils. The method is used to determine pressure heads, flow rates and the "weak points" for internal erosion and structural failures in a saturated soil under excessive pressure gradients. Chapter 4 presents analytical solutions for two-dimensional flow conditions such as regional groundwater flow toward the coastal line, seepage across a dam, and steady flow toward subsurface drains and pumping wells. Various existing equations and their derivations are presented for analysis and design purposes. Chapter 5 presents advanced solutions of seepage based on Conformal Mapping. When flow domains are irregular or unknown, the mathematical solutions get complicated. This chapter provides transformation functions of the Laplace component equations to simplify the complicated boundary conditions. Examples are provided to calculate flow and pressure heads underneath a dam with impermeable cutoff walls or "curtains" in the foundation. Chapter 6 illustrates how to calculate seepage forces using the combined knowledge of soil mechanics and soil hydrology. This chapter is probably the most important one of this book because the interdisciplinary theory is used to explain common issues in soil and water engineering, such as dam and slope instability due to excessive seepage forces at critical points within or around the structure. Soil hydrology and soil mechanics alone can not provide the complete solutions. More importantly, this chapter states design principles and application guidelines.

Providing appropriate drainage or filtering without causing erosion and breakdown of the soil and water structures is a common goal of most applications. Chapters 7 through 11 provide various solutions

to seepage engineering. Chapter 7 illustrates design criteria for the natural soil filters and drainage layers. Chapter 8 is devoted to filters of geosynthetics (plastic products) which have been wildly used in civil engineering since 1980s. The geosynthetic products are used in various forms today including geocomposite, geofoam, geogrid, geomembrane, geonet, geosynthetic clay liner, and geotextiles. Hydraulic testing and design criteria of the man-made materials are illustrated. Chapters 9 and 10 are devoted to hydraulic seepage control and dewatering to facilitate subsurface constructions, enhance slope stability and protect pavement structures. Various design methodologies and charts are given. Chapter 11 exclusively concentrates on seepage designs at waste containment facilities where water and contaminants move mostly in the vadose zone. Water balance calculations and design criteria for various landfill projects and leachate removal systems are presented.

Overall, the book is a valuable collection of very useful analytical and application solutions to seepage problems in civil and environmental engineering. The contents should be very appealing to engineers, scientists, researches and even regulators in the area. One thing I want to mention at last is that almost all the analytical solutions in the book are for the steady state processes which may or may not represent the critical conditions for design. To my knowledge, there exist many available analytical solutions to the transient seepage issues (e.g., the falling of water table from a flat surface to a curved one between two field drains). The math is not too difficult for civil engineering students and researches in the area, but the inclusion would greatly help the researchers and designers to find the most critical conditions. I find it a greater pity that the book did not include Theis' analytical solutions to the unsteady radial flow to wells and a bunch of other modified solutions. These solutions appear in almost every hydrogeology book and provided important in-situ methods (e.g., transient pumping and slug tests) for the estimation of soil and aquifer parameters such as hydraulic conductivity, transmisivity and storativity.