3.6.2. Inverse Methods

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3.6.2.1 Introduction

An adequate hydrological description of water flow and contaminant transport in the vadose zone relies heavily on soil water retention and unsaturated hydraulic conductivity data of the considered spatial domain. The importance of an accurate soil hydraulic description of the vadose zone, including the root zone, is increasingly recognized in the fields of environmental engineering, soil physics and groundwater hydrology. With the current focus on the entire vadose zone, with increasing applications of watershed and land–atmosphere models, the spatial and temporal scales of interest have shifted to larger dimensions. This trend in increasing larger spatial scales brings along with it the presence of increasing soil heterogeneity. Hence, methodologies need to be available that allow for a rapid and accurate soil hydraulic characterization, including its spatial variability.

Currently, many laboratory and field methods exist to determine the highly nonlinear soil hydraulic functions in the vadose zone, represented by soil water retention and unsaturated hydraulic conductivity curves. Most methods require either static or steady-state flow conditions to satisfy the assumptions of the corresponding analytical solution, which can make measurements time consuming. Excellent reviews of these types of direct methods are presented by Dirksen (1991), Reeve and Carter (1991), and in Sections 3.3, 3.4, and 3.5 of this book. In contrast, the inverse modeling approach presented here estimates soil hydraulic properties from transient experiments, giving much more flexibility in experimental boundary conditions than required for steady-state methods. As an additional advantage, inverse modeling allows the simultaneous estimation of both the soil water retention and unsaturated hydraulic conductivity function from a single transient experiment. In other ways, inverse modeling of transient water flow is not much different than methods applied to steady flow. In either case, inversion of the governing equation is required to estimate the unsaturated hydraulic conductivity function from experimental data. Whereas the steady-state methods invert Darcy’s equation, transient methods invert Richards’ equation. Inversion of Richards’ equation requires repeated numerical simulation of the governing transient flow problem. Successful application of the inverse modeling technique improves both speed and accuracy, as there is no specific need to attain steady-state flow.