ground water

Radar Determination of the Spatial Structure of Hydraulic Conductivity

by Greg A. Oldenborger[1], Robert A. Schincariol[2], and Lalu Mansinha[3]

Abstract/

Spatial variability of hydraulic conductivity exerts a predominant control on the flow of fluid through porous media. Heterogeneities influence advective pathways, hydrodynamic dispersion, and density-dependent dispersion; they are, therefore, a key concern for studies of ground water resource development, contaminant transport, and reservoir engineering. Ground-penetrating radar contributes to the remote, geophysical characterization of the macroscale variability of natural porous media. On a controlled excavation of a glacial-fluvial sand and gravel deposit in the Fanshawe Delta area (Ontario, Canada), the hydraulic conductivity field of a 45 × 3 m vertical exposure was characterized using constant-head permeameter measurements performed on undisturbed horizontal sediment cores. Ground-penetrating radar data were collected along the excavation face in the form of both reflection and common midpoint surveys. Comparison of geostatistical analyses of the permeameter measurements and the radar data suggests that the horizontal correlation structure of radar stack velocity can be used to directly infer the horizontal correlation structure of hydraulic conductivity. The averaging nature of the common midpoint survey is manifest in the vertical correlation structure of stack velocity, making it less useful. Radar reflection data do not exhibit a spatial structure similar to that of hydraulic conductivity possibly because reflections are a result of material property contrasts rather than the material properties themselves.

Introduction

Spatial variability of hydraulic conductivity or intrinsic permeability exerts a predominant control on the flow and transport of fluid in porous media. Order-of-magnitude contrasts in hydraulic conductivity may subtly influence the fluid potential and greatly influence the flow field, thereby producing preferential paths for advective transport (Poeter and Gaylord 1990). Furthermore, heterogeneity of hydraulic properties controls the macrodispersive component of the mechanical dispersion of solutes (Gelhar and Axness 1983; Hess et al. 1992) and, in the case of variable density flow, heterogeneities are a controlling factor in the generation of plume instabilities (Schincariol et al. 1997).

Large-scale descriptions of lithofacies and hydrofacies have proven inadequate for accurate predictions of local ground water flow and contaminant transport and dispersion (Gillham and Cherry 1982; Sudicky et al. 1983; Anderson 1989). Koltermann and Gorelick (1996) reviewed several techniques being developed to address the need for increased spatial resolution of hydraulic property field representations. Generally, these representations may take deterministic or stochastic forms, each of which require prior knowledge of both the probability distribution of the hydraulic property and its spatial correlation structure. To this end, the focus of much recent research has broadened to incorporate geophysical tools into deterministic and stochastic estimations of hydraulic properties (Hyndman and Gorelick 1996; Yamamoto et al. 1995; Cassiani and Medina 1997).

Ground-penetrating radar (GPR) is a near-surface electromagnetic geophysical tool described in detail by Daniels (1996) and Reynolds (1997). Geoscience applications of GPR have traditionally focused on qualitative remote-sensing for determining depths to ground water (Arcone et al. 1998), outlining zones of contamination and sea water intrusion (Davis and Annan 1989) and, most commonly, for imaging the structural architecture of the subsurface

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[1] Center for Geophysical Investigation of the Shallow Subsurface, Boise State University, Boise, ID 83725; (208) 426-2716; fax (208) 426-3888; greg@cgiss.boisestate.edu

[2] Department of Earth Sciences, University of Western Ontario, London, Ontario N6A 5B7, Canada; (519) 661-3732; fax (519) 661-3198; schincar@uwo.ca

[3] Department of Earth Sciences, University of Western Ontario, London, Ontario N6A 5B7, Canada; (519) 661-3145; fax (519) 661 3198; lalu@uwo.ca

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