Site-specific soil classification from cone penetration tests and borehole data: a multivariate statistical analysis

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Abstract

Groundwater flow and contaminant transport models are influenced by different kinds of uncertainty, including spatial variability in aquifer and aquitard properties. Appropriate models are developed to support decision making related to environmental impact assessment for waste disposal sites or sites contaminated by point sources, or to develop cost-effective groundwater remediation. These modelling tools are required to incorporate spatial variability possibly observed at different scales. Several studies have investigated correlations between geotechnical data, e.g. cone penetration tests (CPT) results, and hydrogeological parameters such as hydraulic conductivity (*K*). However, examples from using quantitatively geotechnical data in hydrogeological models are very limited, though gathering of such information is usually much easier and cheaper compared to expensive drilling and pumping test campaigns. It is however generally known that CPT soil behaviour type (SBT) classifications are only indicative, and parameters attributed to these SBTs should be treated with caution. Moreover, since most parameters of interest for a groundwater modeling study do not share a one-to-one relationship with the standard CPT parameters, the assessment of the uncertainty related to this relationship is of great importance in stochastic modeling.

Since a unique data set is available for the nuclear zone of Mol/Dessel (Belgium) different approaches to describe the spatial variability in flow and transport parameters can be tested. A detailed hydrogeological characterization reaching depths of 40 to 50 m (including Quaternary and Neogene formations) has been carried out in 2008-2009 coordinated by ONDRAF/NIRAS (Belgian Agency for Radioactive Waste and Enriched Fissile Materials) in the frame of a surface disposal project for low and intermediate short-lived nuclear waste. A large amount of quantitative and semi-quantitative information has been collected in an area of 60 km², including borehole logs, more than 200 CPTs, and roughly 340 *K* measurements on undisturbed cores.

This study uses exploratory cluster analysis to classify this multivariate dataset into different groups. This is achieved with k-means clustering, minimizing the within-group variance. The resulting classes are then interpreted with respect to the site-specific lithotypes using factor analysis. Next, a simplified classification is derived, as it is not possible to distinguish between some groups solely based on CPT data. The resulting classification is compared with literature SBT classifications in relation to the mean and variance of groundwater flow and physical/chemical parameters within each class. Both classifications are also compared in their ability to identify the local litho- and hydro-stratigraphy. Hydraulic conductivity values derived from pore pressure dissipation tests are

compared with estimations obtained from SBT classifications. A final discussion is devoted to the integral scales of the corresponding indicator fields of soil classes and how these differ between the different classification schemes.