High resolution stochastic modelling of aquifers, example for a contamination migration problem.

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Modelling fluid flow and contaminant transfert through homogeneous aquifers is often a mandatory step in a hydrogeological study. Nevertheless, when the assumption of homogeneity is not valid, deterministic simulations prove to be insufficient (Marsily, et al. 2005). The alternative is to use a stochastic model. But in most practical cases the usual analytical approaches (analytical solutions of stochastic partial differential equations) or their simplified numerical counterparts (moment equations) cannot be applied because the assumptions of stationarity of the random functions or the assumptions of small variance (moderate heterogeneity) are not satisfied.

The alternative is to apply a purely numerical approach in a Monte-Carlo framework. In this work, we present some preliminary results of such a study for a contaminated site located in the lower fresh water molasse formation (Keller, et al. 1990) on the western Swiss Plateau. The site has been contaminated by a chemical waste disposal. It has been investigated extensively (see for e.g. Hug 2005) and strong remediation measures have been applied to avoid any further leakage. In the following, we focus only on a part of the test site located at depth within the molasse.

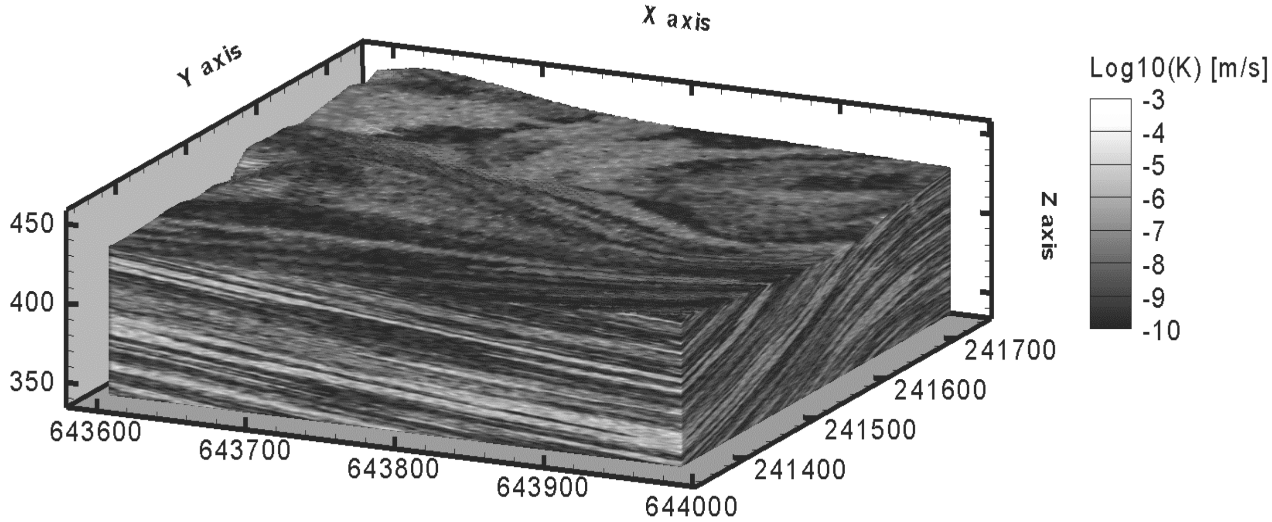

Figure 1. Example of a stochastic realisation of the permeability field (6 million cells). The heterogeneity of permeability within the sedimentary structures is clearly visible (scale in meters).

In a preliminary step, the approach consists in modelling in three dimensions the distribution of the sedimentological structural elements which constitute the fluvial deposit. We distinguish the crevasse splays deposits intersecting levees, and the channel belts meandering through alluvial plains scattered with marshy spots.

Several approaches exist to construct such models (Marsily, et al. 2005). We used the truncated Plurigaussian method (Armstrong, et al. 2003), which is nowadays one of the most advanced from a theoretical point of view and one of the most flexible. It allows satisfying easily local information (such as borehole geological log), and global information (relative disposition of the different facies, extension and thickness of every element, regional dip of layers, or trend in the proportion between the different facies). The facies are then filled with stochastic fields of porosities and permeabilities with standard multi-Gaussian techniques (Fig. 1). The initial contaminant concentration field is estimated within the domain by kriging the values measured in early 2005. The plume evolution for the next 10 years is then simulated with the finite element method for the 100 permeability fields realizations.

The result consists in the statistical distribution of the contaminant concentration in all the points of the domain and at any time. It allows for example to estimate the probability that the contaminant will leave the system above a certain threshold concentration. For example, the model also allows estimating the locations where such a probability is the strongest.

Like every model, this model suffers from several limitations that should not be forgotten. When predicting flow over the next 10 years, we make the very strong assumption that the flow conditions will not drastically change. In this version of the model, we also do not investigate the uncertainty that may result from an inaccurate knowledge of the actual distribution of the concentration.

But, behind the demonstration example, it is important to remind that if such method helps in understanding the flow and transport dynamic in a complex system, it will never provide a definitive answer to the decision maker. Its main interest lies in the fact that it must be used to investigate the reliability of different management decisions. The point is often not so much to know precisely the reality but to take rational decisions, i.e. decisions that will have the highest probability of success, or the lowest probability of failure, within the current state of knowledge.

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