SUPPLEMENTARY MATERIAL

This supplementary material includes the detailed formulation differential equations for steady-state and transient fluid flow, as well as mass transport in porous media as used in FEFLOW (Diersch, 2014) and applied in this study.

Model formulation

The groundwater flow equations for 2D homogeneous anisotropic fully saturated confined aquifers are described as:

$$S_s \frac{\partial h}{\partial t} = K\left(\frac{\partial^2 h}{dx^2} + \frac{\partial^2 h}{dz^2}\right) \tag{1}$$

Where S_s is specific storage coefficient (m^{-1}), h is hydraulic head (m), K is hydraulic conductivity (m/s), t is time (s), and the coordinate axes (x, z) coincide with the hydraulic conductivity axes.

The mass conservation equation can be written as:

$$\frac{\partial \emptyset(C)}{\partial t} + \nabla \cdot (\boldsymbol{q}C) - \nabla \cdot (\emptyset \boldsymbol{D} \nabla C) = \emptyset f \tag{2}$$

Where C is the salinity concentration, N is porosity, q is the Darcy velocity vector, **D** is the hydrodynamic dispersion tensor [L^2 T^{-1}], and f is a source term. D is assumed to be independent of concentration C and its gradient. It is however considered to be a function of the flow velocity q and is commonly described by the dispersion relationship for a porous medium:

$$D_{ij} = \emptyset D_d \delta_{ij} + \alpha_T v_q \delta_{ij} \,(\alpha_L - \alpha_T) \frac{v_i v_j}{v} \tag{3}$$

Where D_d is the molecular diffusion coefficient [L^2 T^{-1}], $\forall_L$ and $\forall_T$ are the longitudinal and transverse dispersivity, respectively [L], and v is the average Darcy velocity [L T^{-1}].

To account for variable-density effects in the flow system, equations 1 and 2 are coupled with the density-dependent Darcy vector q, as:

$$\boldsymbol{q} = -\frac{k}{\mu}\left(\nabla P^R - (\rho - \rho_o) g\right) \tag{4}$$

Where k is permeability [L^2], : is dynamic viscosity [M L^{-1} T^{-1}], P^R is relative pressure [Pa], $\boldsymbol{\rho}$ is the fluid density [M L^{-3}], $\boldsymbol{\rho_o}$ is the initial fluid density [M L^{-3}], and *g* is the gravitational acceleration [L T^{-2}].

The average Darcy velocity is:

$$V = q/N \qquad (5)$$

The relationship between hydraulic conductivity, K (m/s), and permeability k (m^2) is:

$$K = \frac{k\rho_o g}{\mu} \qquad (6)$$