Ability of Single-Well Injection-Withdrawal Experiments to Estimate Ground Water Velocity

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Objective

Experiments
- Interwell
- Intrawell
- SWIW (Push-Pull)

Tracers
- conservative
- reactive
- sorbing

Quantities
- ambient groundwater velocity
- residence times
- inter-/surfaces etc.

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Governing Equations

Dispersion-advection-equation:

\[ \phi_{\text{eff}} \frac{\partial c}{\partial t} - \nabla \left( \left( D_{\text{disp}} + D_{\text{diff}} \right) \nabla c \right) + v \nabla c = 0 \]

\[ D_{xx} = \alpha_l v_x^2 + \alpha_t \frac{v_y^2}{\langle v \rangle} + D_{\text{diff}} \]

\[ v = \frac{-K}{\rho W g} \nabla p \]

or analytical solution
Model approach

\[
\bar{c} = \frac{\int v \cdot c}{\int v}
\]

Initial condition
\[ c = 0 \]
Boundary condition
\[ c = 1 \]

\[
(c-1) \cdot (t \leq t_l) + (v_n \cdot n_x + v_y \cdot n_y) \cdot (t > t_l) = 0
\]
Model approach – Modes

DI & esst:
Solution transfer
Intermediate time stepping

Esst:
Solution transfer

Pde:
Boundary condition change

<table>
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<tr>
<th>MODEL</th>
<th>DOF</th>
<th>TIME [s]</th>
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<tr>
<td>pde</td>
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Results - Sensitivity

\[ \phi_{eff} \frac{\partial c}{\partial t} - \nabla \left( \left( D_{disp} + D_{diff} \right) \nabla c \right) + v \nabla c = 0 \]
Results – Ambient Groundwater Velocity

Type 1

Type 2
Results – Ambient Groundwater Velocity

Type 2

Type 3
Results – SWIW

- Eff. Porosity: 0.3
- Dispersivity: 0.0025 m
- Darcy velocity: $1.1 \times 10^{-6}$ m/s
Conclusions

- High sensitivity on dispersivity
- Lower sensitivity in eff. porosity
- In dependence on the ambient ground water velocity we get three main type-curves shapes
  - Good fit of the measured BTC with the modeled BTC for a homogenous aquifer
  - Change of the boundary-type is possible
Outlook

- Implementation of well effects (e.g. skin effect)
- Considering of inhomogeneities (e.g. fracture flow)
- Tracer effects like sorption and reaction
Thank you for your attention!

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