Modeling water flow in a tile drainage network in glacial clayey tills in an agricultural catchment

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INTRODUCTION

Tile drainage is a widespread water management practice applied at poorly drained production fields for optimizing crop productivity and for avoiding waterlogging. One of the key aspects of water resources management issues in agricultural catchments is the ability of properly understanding and quantifying the role of tile drainage, which may be of prime importance in the catchment water balance. Few numerical modeling methods have been tested in previous studies to evaluate the impact of tile drainage at field scale or catchment scale. It is still a challenge to represent correctly subsurface drainage networks in numerical models while accounting for their influence on water flow and transport.

Objectives
- Hydrological modeling of water flow at field scale.
- Assess the contribution and impact of tile drains on water budgets.
- Test various mesh elements sizes along the drains to check the influence of refinement on the results.

NiCa Research Project

- Focus: nitrate reduction within geologically heterogeneous catchments in Denmark.
- Aim: develop tools for estimating nitrate reduction rates in the saturated and unsaturated zones under agricultural conditions.
- Assumption: a good prediction of nitrate reduction in the soil relies on an appropriate characterisation of geological heterogeneity.
- Methodology:
  - Airborne geophysical mapping.
  - Geological modeling.
  - Hydrological modeling.
- Representative Elementary Scale definition.

Further info @ http://www.nitrat.dk

STUDY AREA

- Lillebæk catchment: 4.7 km² monitored catchment on Funen Island, Denmark.
- Land use: agriculture (88 %), forests and other nature (7 %), roads and buildings (5 %).
- Important contribution of drainage water flow on stream discharge.
- Quaternary deposits (30 to 60 m thick), overlaying limestones and confined sandy aquifer.
- Upper glacial clayey till (Weichsel).
- Interglacial - Lower glacial clayey till (Saale).

Environmental modeling

- Hydrological modeling
  - HydroGeoSphere (Therrien et al., 2013): fully integrated physically-based 3D surface subsurface flow and transport model.
  - 3D domain generated from the 2D mesh, based on a national scale danish geological model (DEMs): 114213 elements, 64440 nodes, 725 elements with drain nodes.

Model setup
- Fully coupled 2D surface water and 3D variably-saturated groundwater flow model.
- Tile drains buried at 1 m deep, diameter = 0.1 m, channel boundary condition.
- Lateral and bottom boundaries: no flow.
- Overland flow: runoff, no stream.
- Model run: 3 months w/ precipitation, 4 day-precipitation event, 3 months w/o precipitation.

MESH REFINEMENT INFLUENCE

- Refinement of mesh elements along discrete drains: 2 m (reference model), 5 m and 1 m to the side.
- Total sources/sinks water volume: equivalent order of magnitude for all cases.
- Overestimated tile drainage values (4% more of V lateral), higher water flow peaks.
- Slightly underestimated surface water flow.
- Overestimation for coarser elements.
- Overestimation for finer elements.

CONCLUSION

Observations
- Good response of tile drainage to precipitation.
- Tile drainage main water flow output.
- Various element sizes along drains show different results:
  - Drainage overestimation for coarser elements.
  - Overland flow overestimation for finer elements.

Further developments
- Test various combinations of boundary conditions and model setups to define the most realistic and less time-consuming method for 3D tile drainage modeling at field scale.
- Develop a larger scale model.

References


Modified after Refsgaard et al., 2013

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Further developments

Good and quick response of drainage to precipitation peaks.
- Back to base flow in ~ 10 days.
- Tile drainage flow rate values are higher than overland flow rate.
- Overland flow: no response for 1° peak –Recharge.

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