GROUNDWATER FLOW PECULARITIES INDUCES BY POST-GLACIAL AND MODERN KARST FEATURES

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Introduction

Quaternary karst environments often have complicated groundwater flow system because of sinkholes and underground conduits. It is complex task to understand groundwater flow pattern in such conditions therefore several approaches needs to be used in order to determine groundwater flow regime and specific underground connections. Skaistkalne vicinity is excellent place where investigate groundwater peculiarities induced by post-glacial and modern karst features, like sinkholes of different shapes and ages and underground conduits. Two rivers – Memele and Iecava makes this place more complex because of their close location (2.6 km) and significant water level differences (up to 7 meters). Tracer test experiment was conducted and numerical model was created to understand groundwater flow peculiarities in research area.

Methods

The research was done by using direct measurenments and model calculations. Connectivity of the two rivers was tested by applying tracer test where 0.6 kg of uranine were injected into the river 1 one kilometer upstream from possible water linkage area. Groundwater from monitoring wells were analyzed by GGUN-FL24 Fluorometer and adequate calibration was made beforehand. Fluorometer was installed in well No. 7 while other monitoring wells were sampled in plastic bottles and analyzed by fluorometer afterwards. Hydrogeological model was made for territory of 12 km^2 including area of specific interest – territory between both rivers (Fig. 6). Model was built within MOSYS modelling system. A 3D Darcy flow with free-surfaces and anisotropic conductivity is assumed for the steady-state solution. As boundary conditions, water level of largest rivers, known karst lakes and ditches were defined as tophead in uppermost layer. Karst affected area was treated like "honeycomb" structure (Fig. 7), where karst conduits were defined within comb frames.

Site description

Karst processes are found at several locations in Latvia (Fig. 1), including southern part, where karst in gypsum layers takes place.
Study area covers territory between two rivers Iecava and Memele (Fig. 2) with water level difference of 7 meters and horizontal distance of 2.6 kilometres between both. Confined – unconfined groundwater is bound to the Salaspils aquifer lying at the depth of 10-15 m below ground surface.

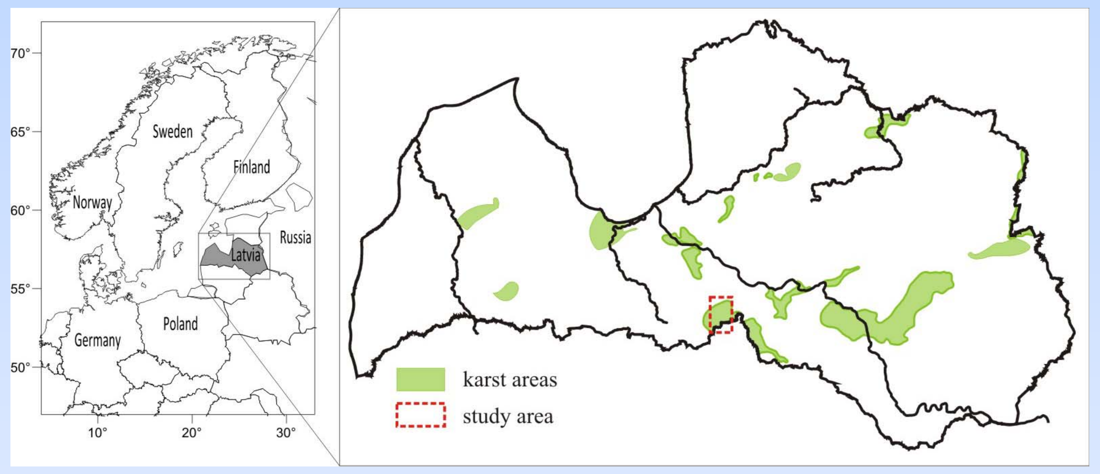

Fig. 1. Location of study site and karst areas in Latvia

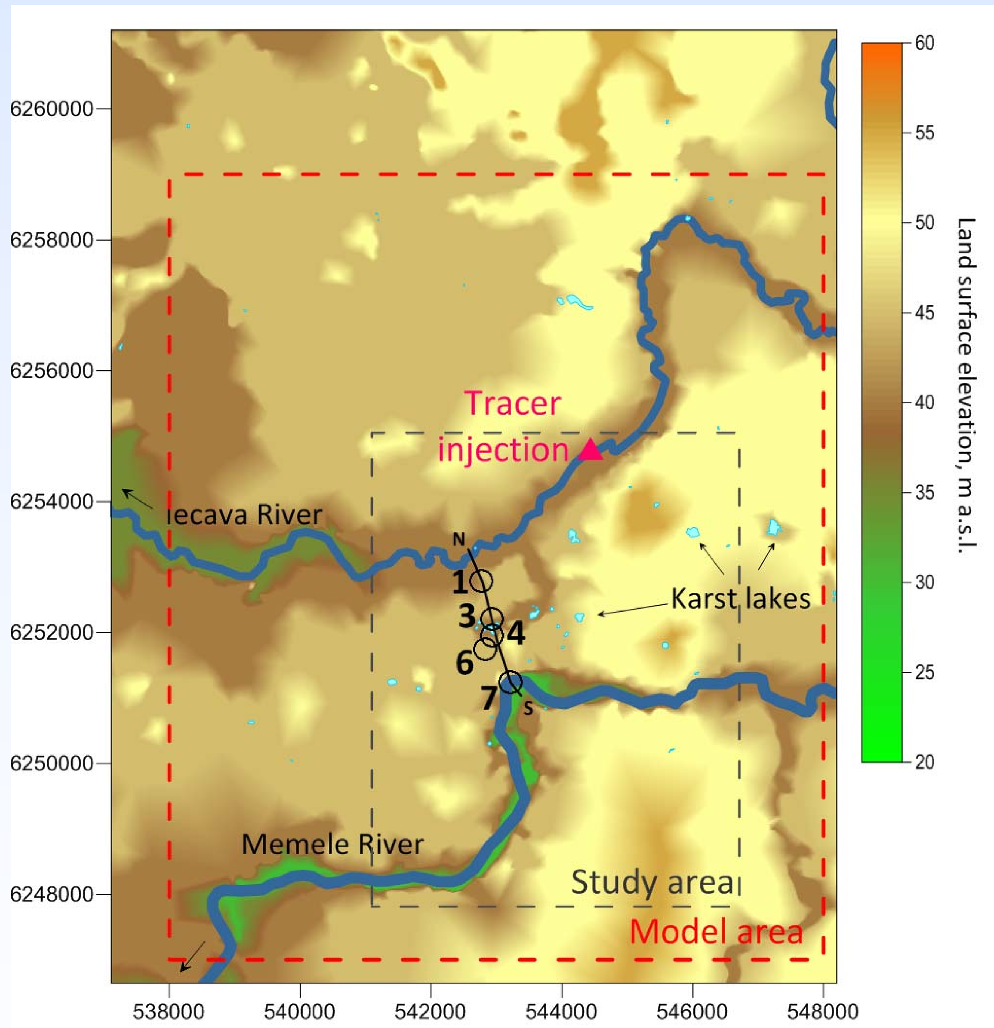

Fig. 2. Study area showing location of observation wells, tracer injection point, geological section line and numerical model area.

There are Upper Devonian Salaspils Formation sediments consisting of gypsum and carbonaceous rocks covered by Quaternary low to high permeable deposits (Late Weichselian till and glaciofluvial sand, Holocene alluvium) found at the study area.
Quaternary karst processes have affected Upper Devonian gypsum and carbonaceous rocks, and surface and underground karst features like sinkholes and karst lakes as well as highly permeable zones of fractures and channels are present in the area. Salaspils Formation has very complicated structure, where gypsum layers are interbedded with dolomite, clay and marl layers (Fig. 3).
Pleistocene deposits are low to high permeable, vary in thickness from 5 m to 25 m. Quaternary sediments are separated from Upper Devonian Salaspils formation by very low permeable clay layer and till. Therefore Salaspils formation has confined aquifer conditions although surface water from the River Iecava and sinkholes might intrude at some degree.

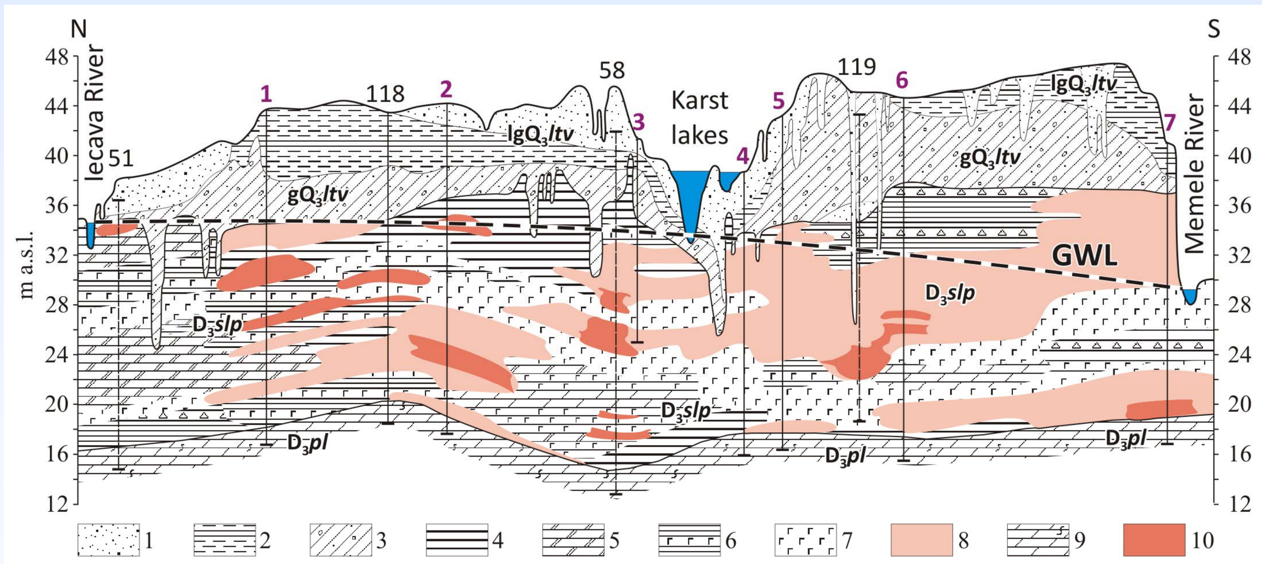

Fig. 3. Geological section of the study area along the line of sampled wells (Nos. 1; 3; 4; 7), the length of the section is 2.6 km (Tracevska et al. 1986)
Legend: 1 – sand, 2 – silt, clayey silt, 3 – till loam, 4 – carbonate clay, 5 – marl, dolomite marl, 6 – clayey gypsum, 7 – gypsum, 8 – dissolved gypsum strata with clay and dolomite flour, 9 – dolomite, fractured dolomite, 10 – karst cavities, partially filled with dolomite flour; GWL–groundwater level; lgQ$_3$ltv–glaciolacustrine sediments, gQ$_3$ltv – glacigene till deposits, D$_3$slp – Upper Devonian Frasnian stage Salaspils Formation sediments, D$_3$pl – Upper Devonian Frasnian stage Plavinas Formation.

Results

Connection between Iecava and Memele Rivers through post-glacial karst environment was investigated by tracer test yielded out at medium-level water conditions. 600 grams of fluorescent colour were injected into Iecava river about 1 km upstream from potential leakage area (fig. 2). Several wells were observed by fluorometer and by sampling in order to detect traces of dye. Tracer test results showed that conduits are characterized by high permeability and they connect both rivers as well as karst lakes. Based on tracer test, groundwater velocity reaches 800 – 1300 m/day in conduits. Concentration profile of recovered fluorescent dye imply complicated groundwater channel system characterized by inter-connected conduits (Fig. 4).

Uranine was detected in well No.4. as well by analyzing collected samples at different time. Two peaks can be observed although it's possible that some fluctuations has been between sampling times (Fig. 6). Sampled water had different turbidity values because of iron sedimentation during storage and it may affect uranine measurements.
Three tracer concentration peaks were observed in well No.7 with 30 minutes of delaying between each peak. Modeling results showed that at well No7. groundwater tends to convergence therefore it is likely that main flow divides and connects together afterward thereby explaining several close-standing tracer peaks. Total mass of 5.23 grams of uranine flowed through the well No.7.

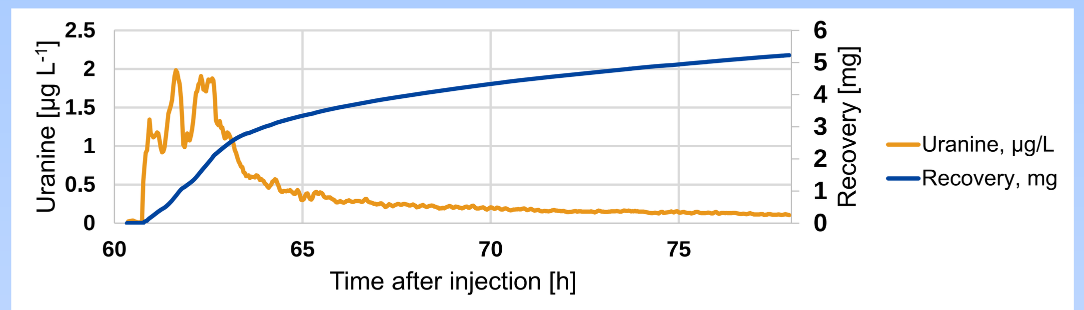

Fig. 4. Uranine concentration and recovery in well No.7

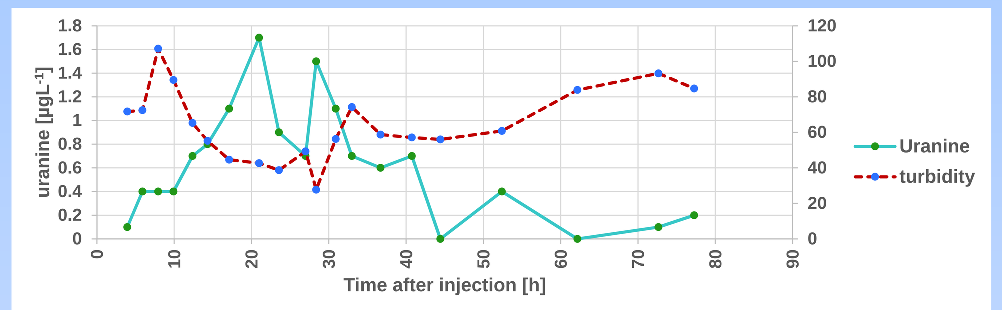

Fig. 5. Uranine concentration and turbidity in well No.4

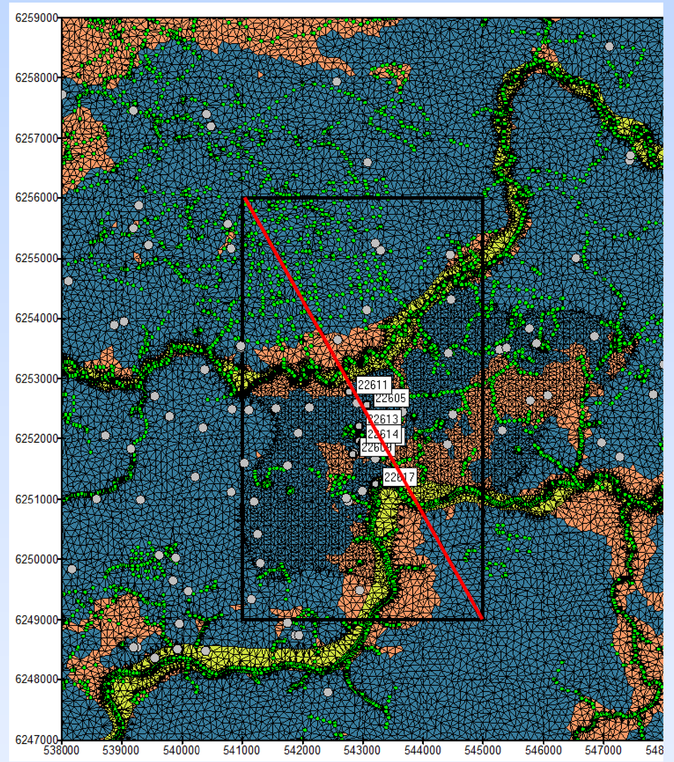

Fig. 6. Model setup: black frame – area of interest; green dots – assigned tophead; numbers – calibration wells; grey dots – wells for geometry building; red line- cross section (see Fig. 9.)

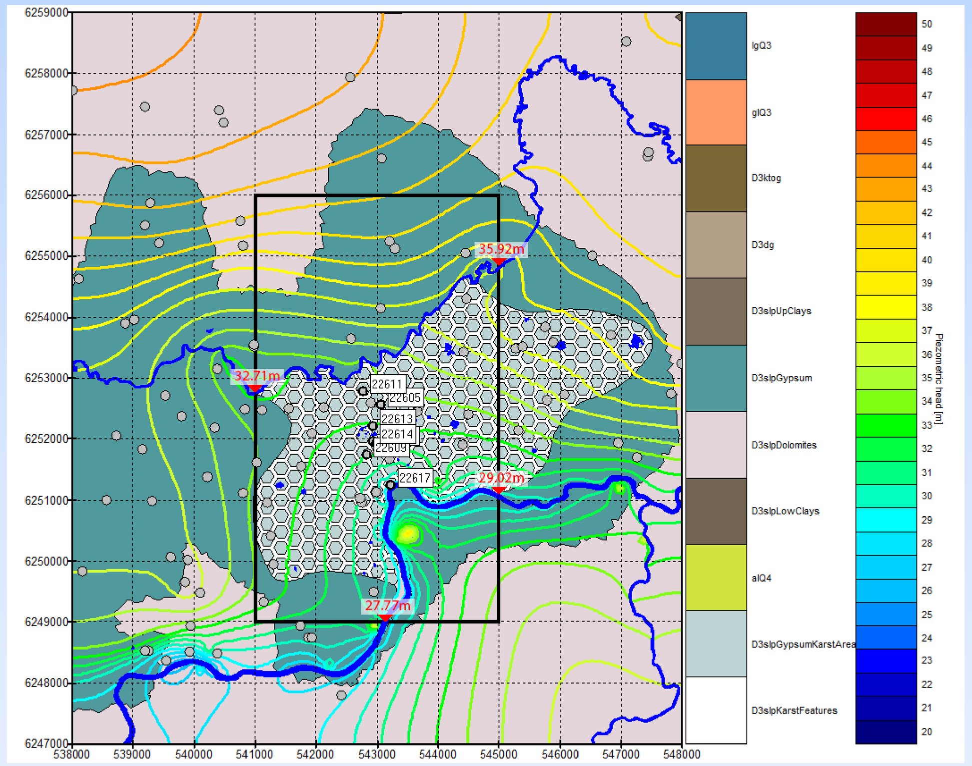

Fig. 7. Calculated pjezometric head in Salaspils aquifer in area of two rivers (blue lines); observed water level in both rivers are in red colour.

Introduction of honeycomb structure in the module significantly improved results, comparing to the previous model (Delina et al, 2010), where highly permeable continuous layer was used to represent karst features in the Salaspils aquifer. Modelled piezometric heads in Salaspils aquifer allows to delineate potential pathways of the tracer (Fig. 7), and this corresponds to the fact that tracer was not observed in wells closer to Iecava river. Cross-section view (Fig. 8) assures that Iecava river drains only Quaternary sediments, and recharges Salaspils aquifer in the study area, but Memele river is major drain in the area collecting unconfined and confined groundwater there.

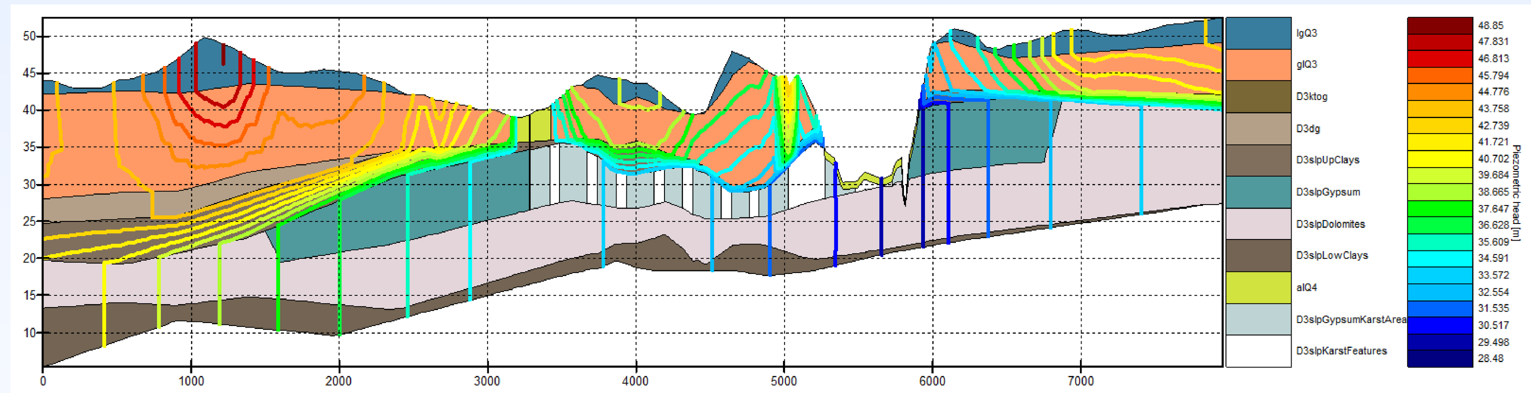

Fig. 8. Cross section of modeled area (see Fig. 6.) with pjezometric heads

Conclusion

Groundwater flow regime in research area is greatly influenced by post-glacial karst processes. Iecava River has connection to groundwater therefore river water favours karst process activity until today.
Numerical model for research area was created by applying all available geological information combined with results from tracer test. New technique called honey-comb structure was implied in model in order to simulate karst environment. All known Quaternary sinkholes were included in model as well as both rivers and underlying Q3 and Q4 alluvial sediments. Model yielded good results as it fitted well with observed water levels in monitoring wells. Numerical model showed that post-glacial karst processes has influence on groundwater flow distribution caused by sinkholes and developed underground conduits. The best model results were observed when horizontal hydraulic conductivity for gypsum conduits in honey-comb structure was set to 570 m/day.

References

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