ESF Project „*Establishment of interdisciplinary scientist group and modelling system for groundwater research*”

Transient modelling of groundwater dynamics in the Baltic Artesian Basin

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Project Nr. 2009/0212/1DP/1.1.1.2.0/09/APIA/VIAA/060

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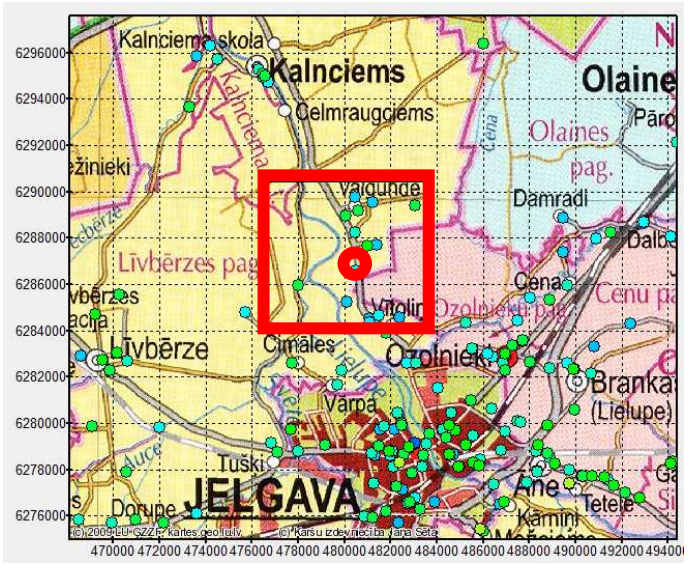
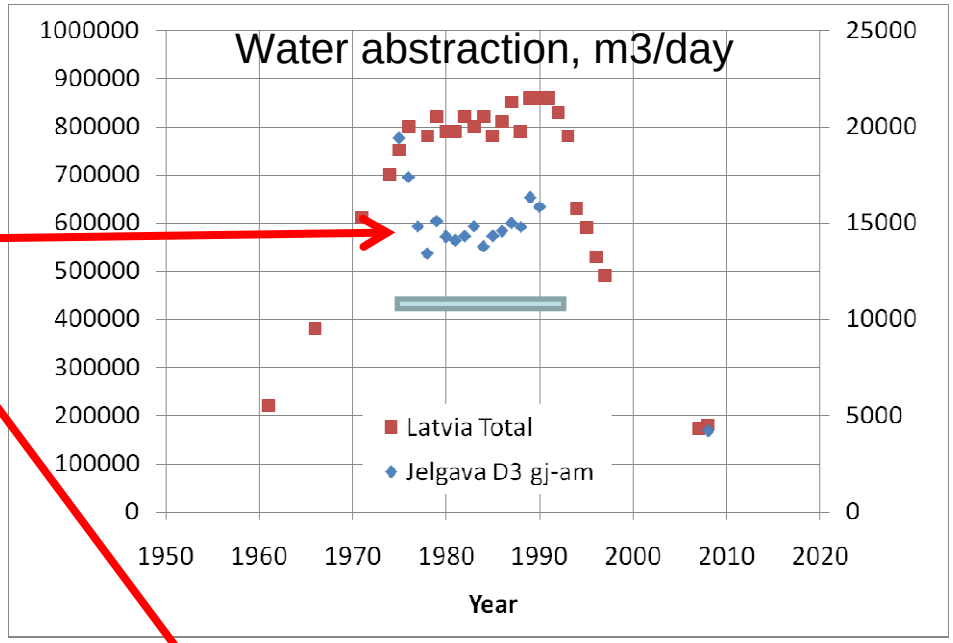
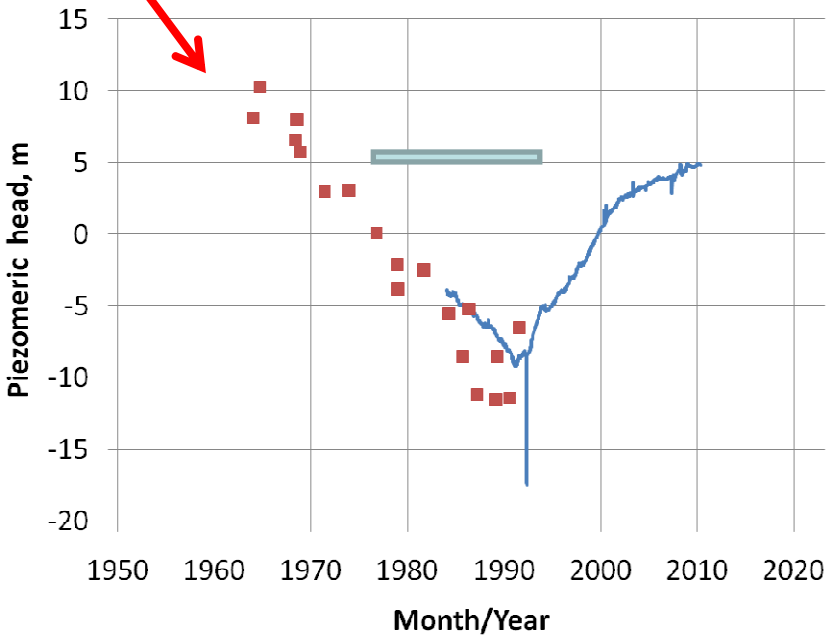
Motivation for transient simulation

Constant abstrction 1971-1991
Decreasing piezometric head







Equations for transient groundwater flow

$$\nabla \cdot \left(K \nabla h \right) = -q_V$$

Steady state flow

$$S_s \frac{\partial h}{\partial t} = \nabla \cdot \left(K \nabla h \right) + q_V$$

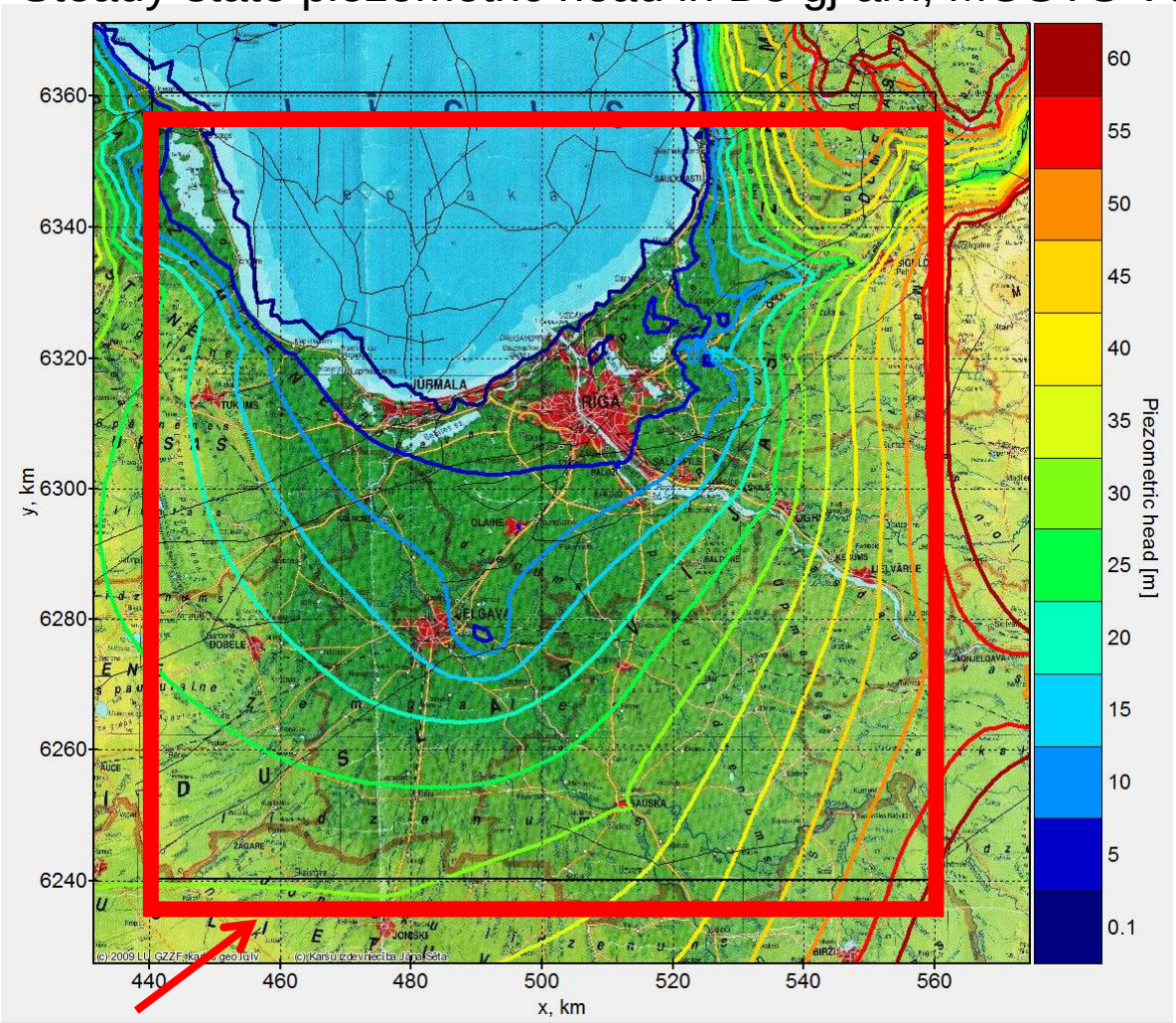
Transient flow

$$S_s = \rho_w g \left(\beta_p + n \beta_w \right)$$

for confined aquifer

Simple model

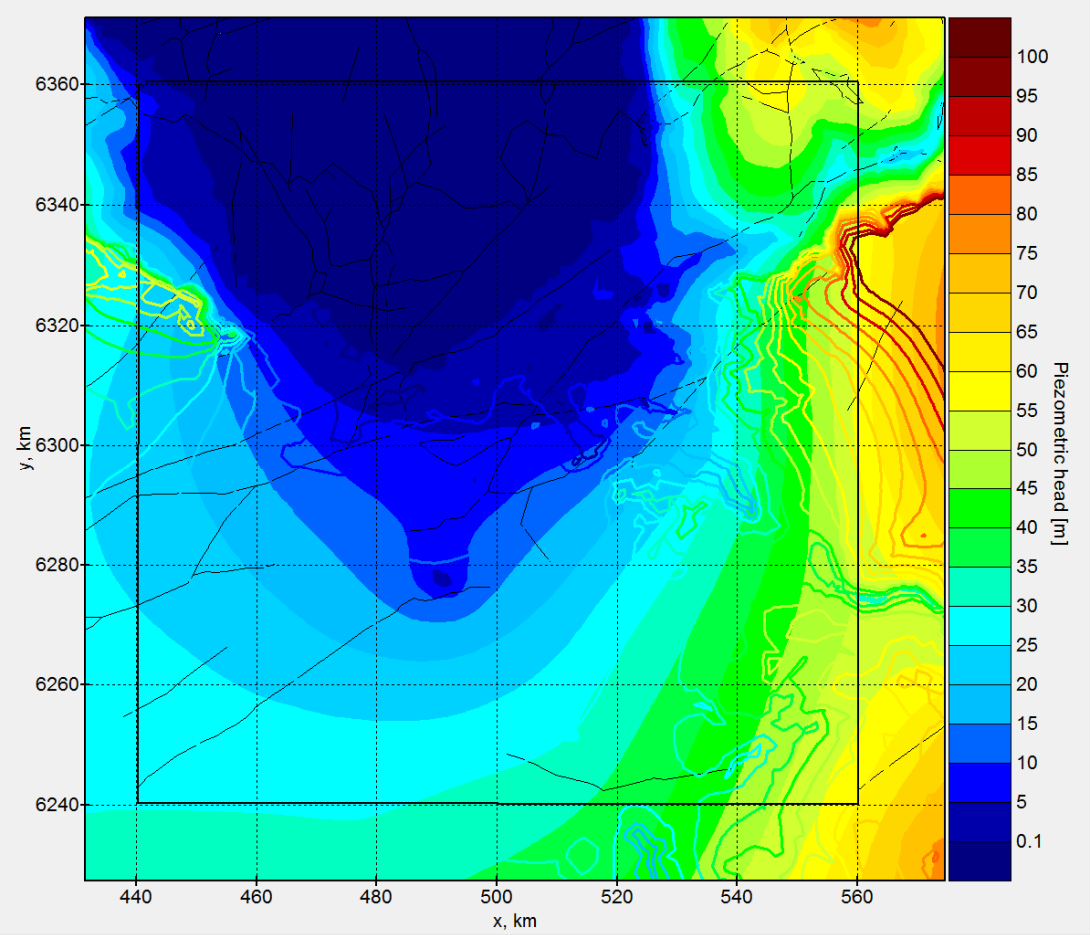
Steady-state piezometric head in D3 gj-am, MOSYS V0



Boundary for simple model; fixed piezometric head from MOSYS V0

Simple model

D3 gj-am (filled) vs. D3 pl-dg (lines)

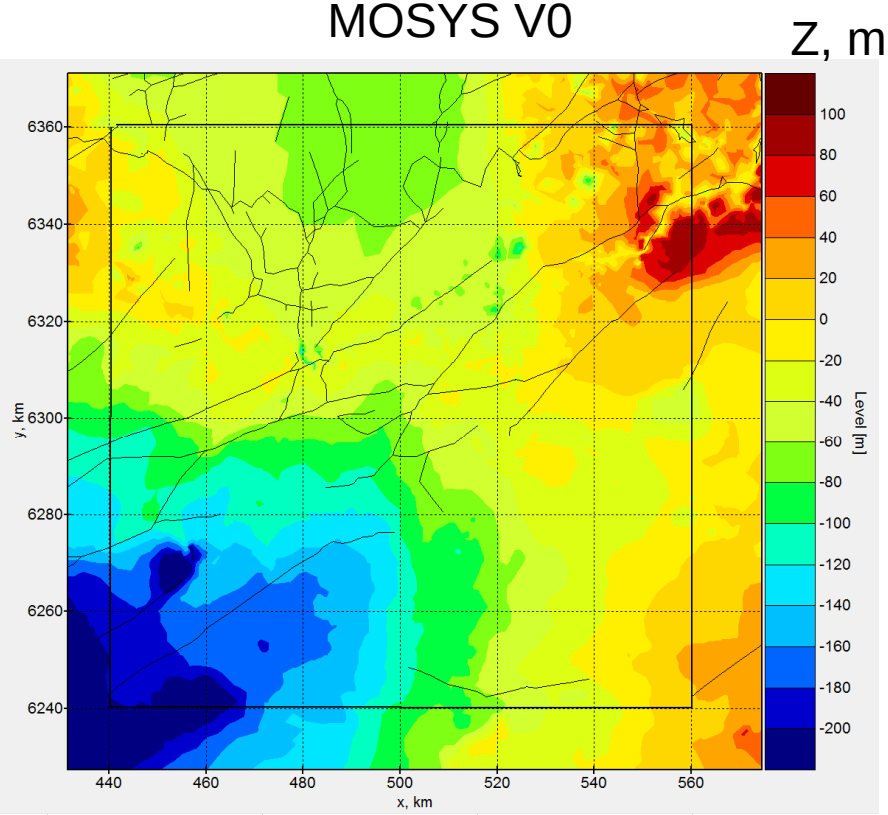


There is no distinct flow between layers – the use of simple one layer model is reasonable

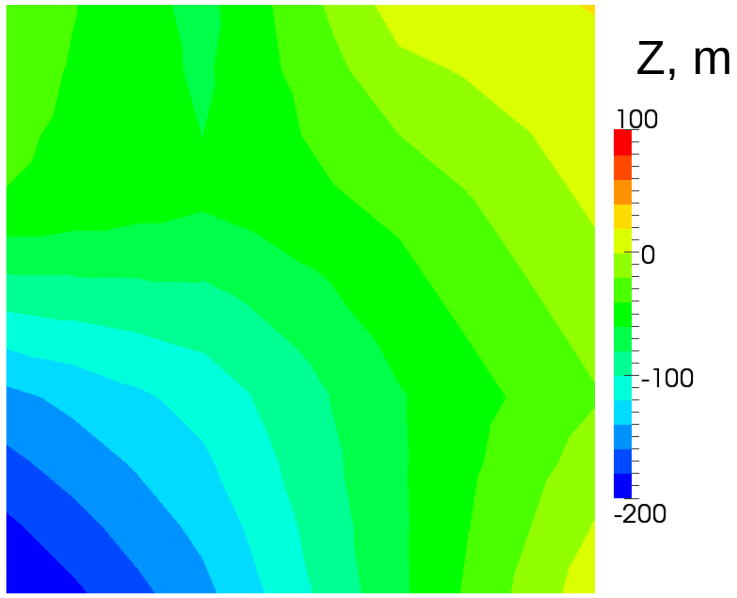
Simple model

Top surface of D3 gj-am

MOSYS V0

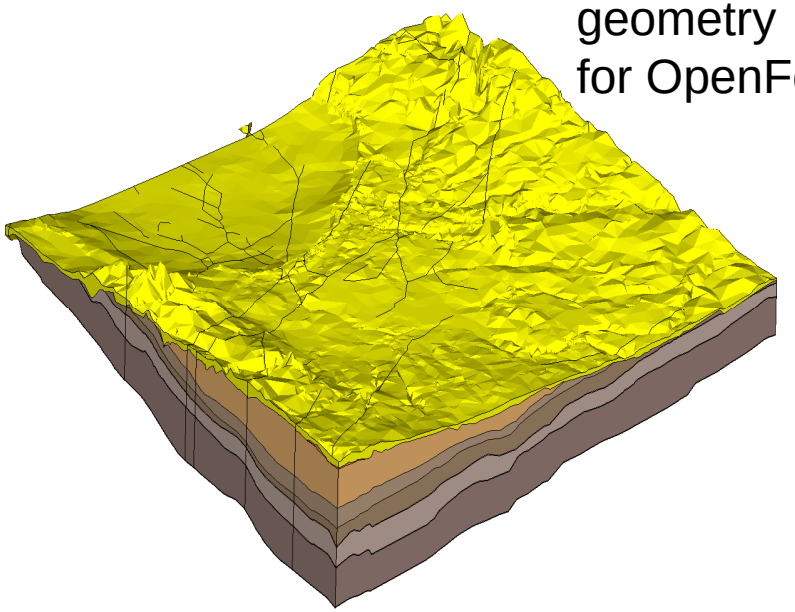


Simple OpenFOAM

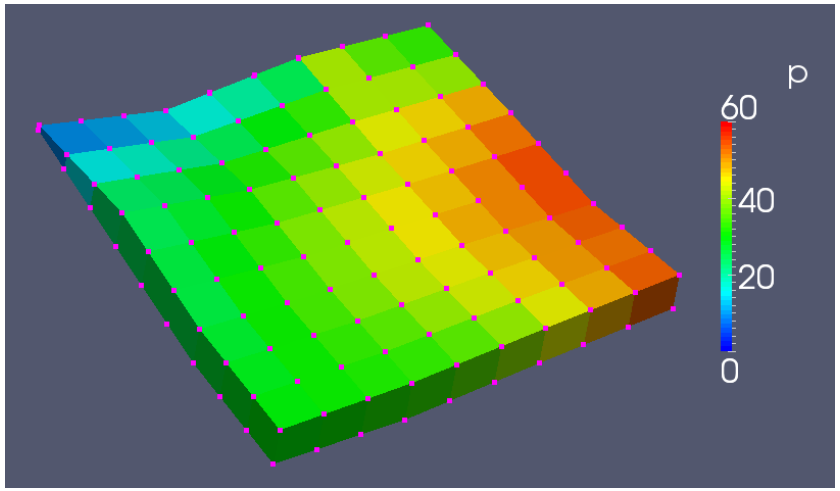


Simple model

MOSYS V0 geometry



Simple D3gj-am geometry for OpenFoam



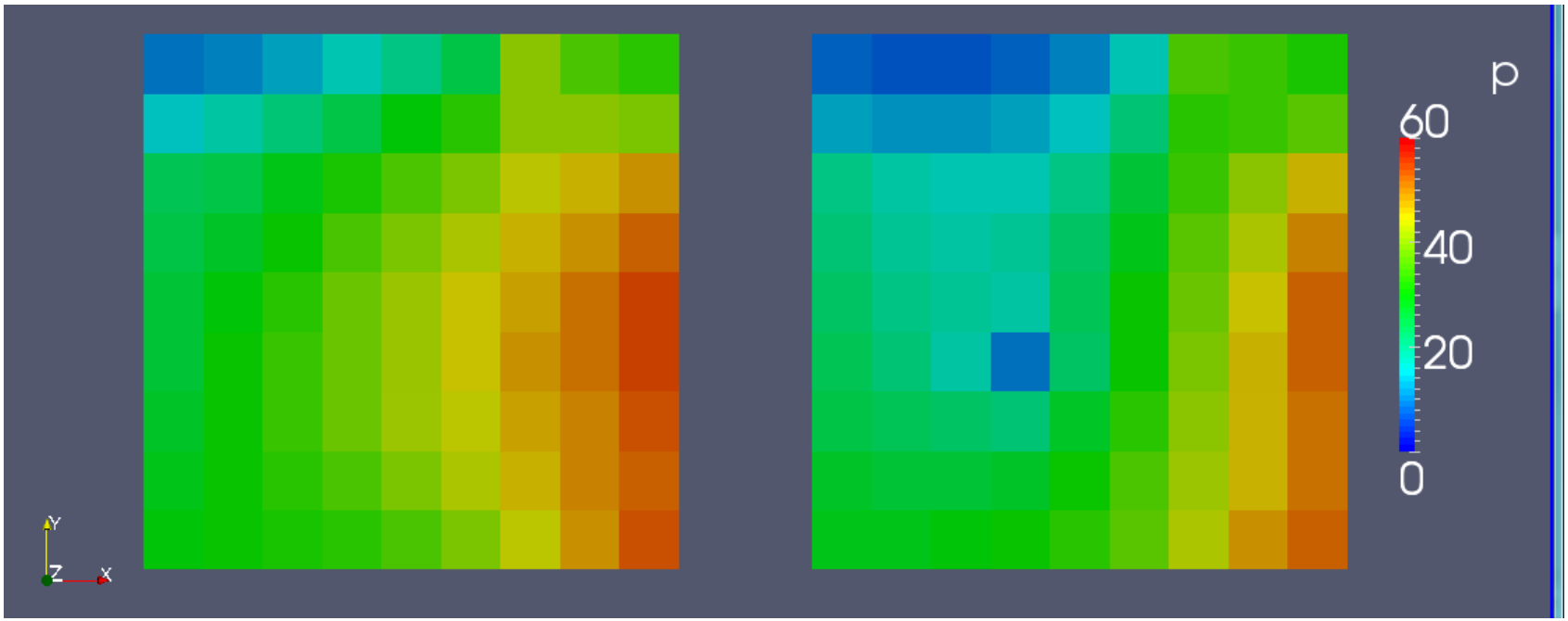
OpenFoam potentialFoam solver is used as a basis for development of groundwater flow model

```
    fvScalarMatrix pEqn
    (
        fvm::ddt(Ss,p)
      - fvm::laplacian( cond, p)
      - Q
      ==
       - fvc::div(phi)
    );

    pEqn.setReference(pRefCell, pRefValue);
    pEqn.solve();

    if (nonOrth == nNonOrthCorr)
    {
        phi += pEqn.flux();
    }
}

Info<< "continuity error = "
    << mag(fvc::div(phi))().weightedAverage(mesh.V()).value()
    << endl;

U = fvc::reconstruct(phi);
```

Simple model

Flow is first stabilized for 300 years to reach steady state solution without water abstraction.

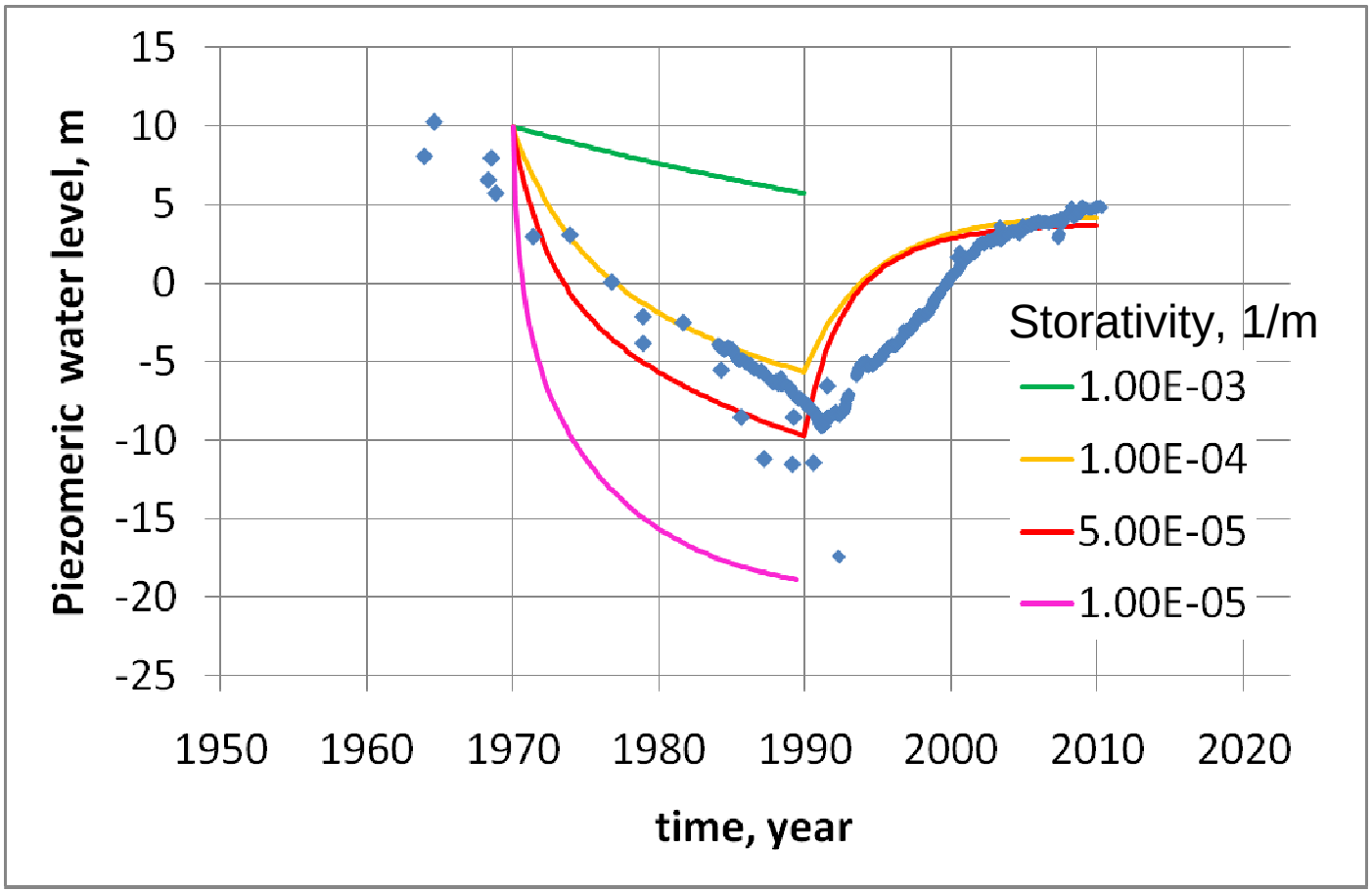
The water abstraction of 15000 m3/d is applyed near Jelgava for 20 years



Simple model

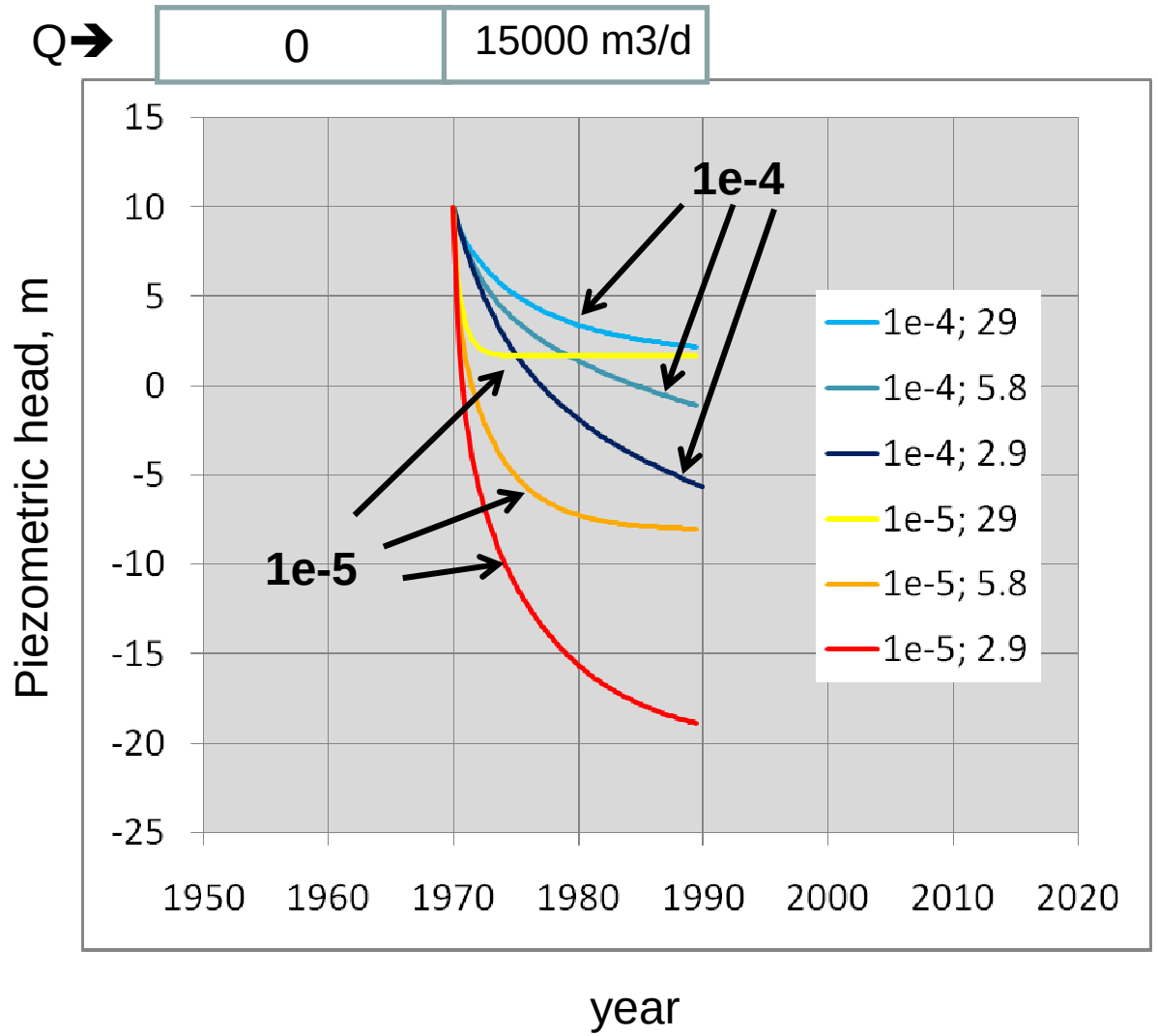
Piezometric head in Jelgava as a function of storativity

Q➔	0	15000 m3/d	5000 m3/d



Simple model

Effect of hydraulic conductivity



Higher conductivity decreases the relaxation time and the head difference

MOSYS transient

New executable CalculateUnsteady.exe

New algorithm for unconfined zone

New ini-file

"MeshIn=BAB_V0Combined_4.str";"HeadOut=V0_JV_Em4_stac.p";"HeadIn=V0_test_3ini4000.p";"Infiltration=infilt.ez";"TopHead=tophead.z";"Extraction=udensieguve_pecLevina.txt"; "StartDate=1600.01.01"; "EndDate=1900.01.01"; "TimeStep=30"; "OutputFrequency=60"; "Tolerance=1e-6";"MaxIterations=200";"InfiltRelaxation=1e-7"

New format of water abstraction file

nr	x	y	depth1	depth2	1940.01.01	1950.01.01	1960.01.01	1970.01.01	1980.01.01
2	576182	6273881	93	164	137.97	459.9	1287.72	3541.23	4599
3	566537	6274586	95	120	35.07	116.9	327.32	900.13	1169
4	587401	6279024	90	128	15.57	51.9	145.32	399.63	519
5	607281	6276589	100	130	25.53	85.1	238.28	655.27	851

Modified HiFiGeo

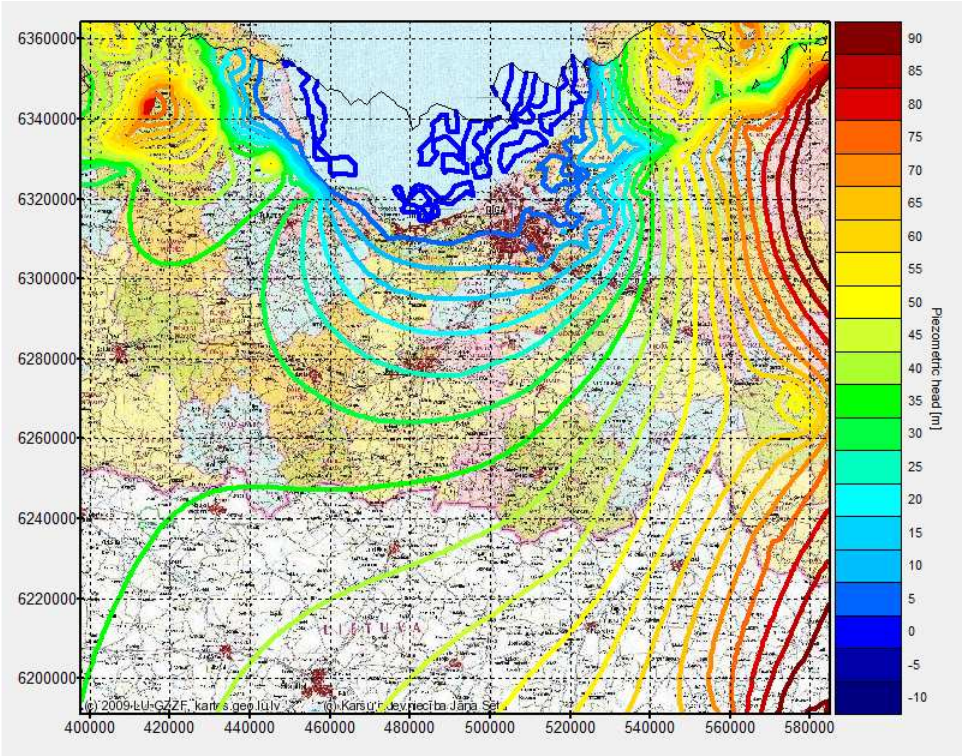
MOSYS transient

Geometry BAB V0

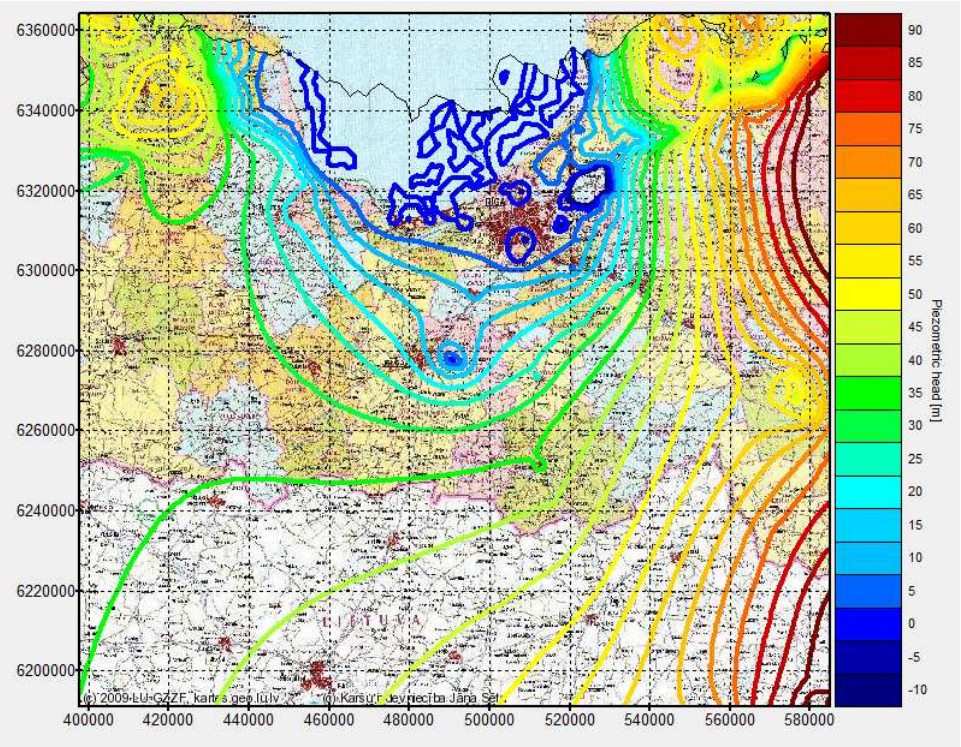
Three cases with different storativities: 1e-2; 1e-3; 1e-4

Storativity 1e-4 1/m

1940



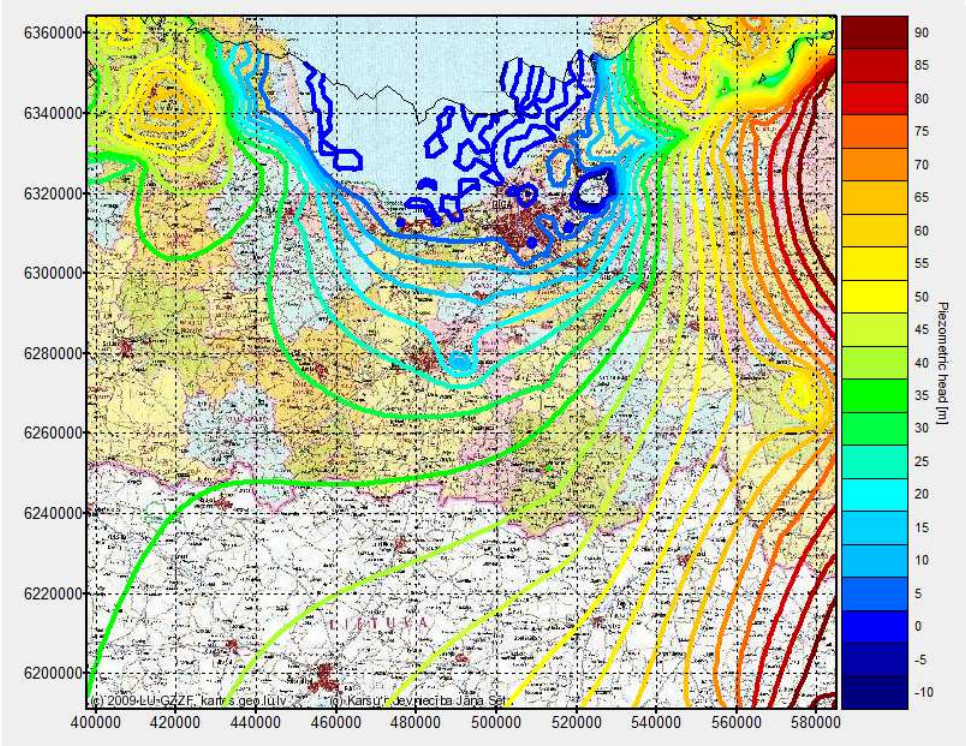
1990



MOSYS transient

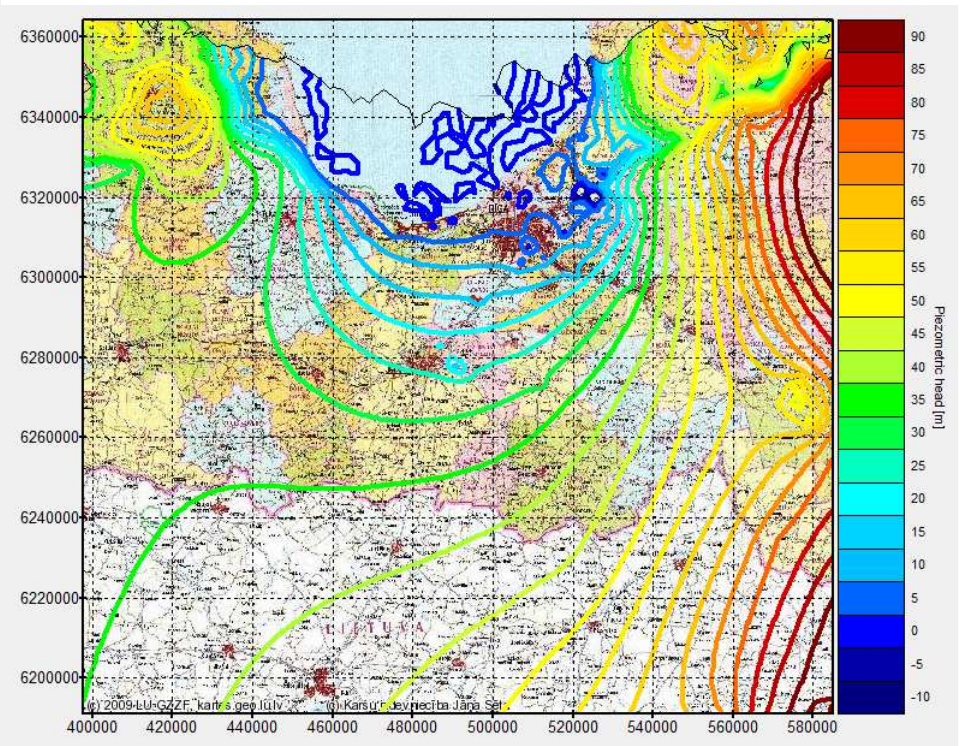
Storativity 1e-3 1/m

1990



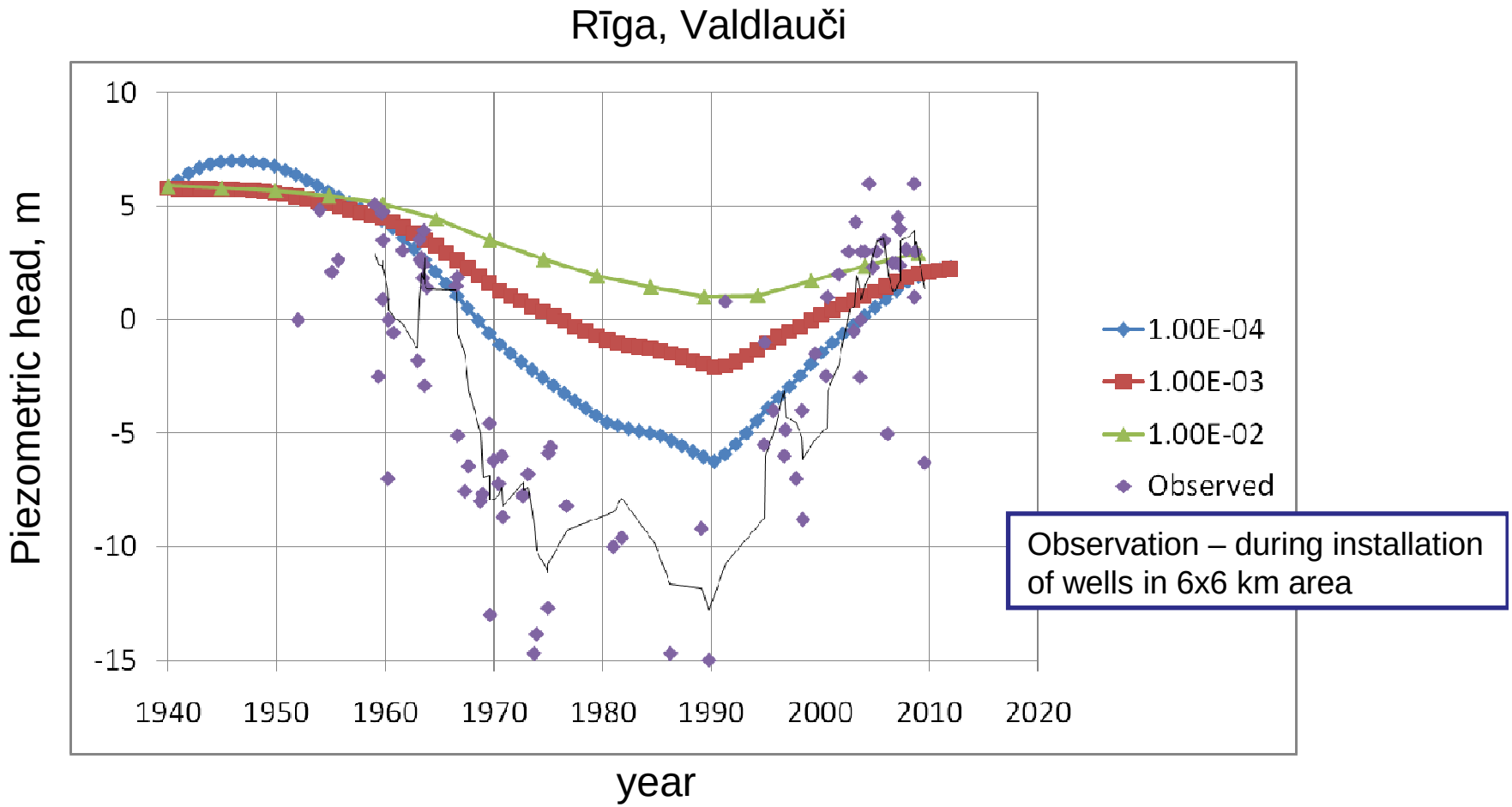
Storativity 1e-2 1/m

1990



Smaller depression with higher storativity

MOSYS transient



Reasons for differences (abstraction, conductivities, storativity) should be clarified

Conclusions

• Transient groundwater flow models are implemented and tested in OpenFoam and MOSYS

• Simple model demonstrates that the combination of abstraction, storativity and conductivity prescribes the development of depression cones

• The transient solver in MOSYS is ready for groundwater studies in BAB

The present work has been funded by the European Social Fund project „Establishment of interdisciplinary scientist group and modelling system for groundwater research" (Project Nr.2009/0212/1DP/1.1.1.2.0/09/APIA/VIAA/060)