GEMTool, an Instrument for Assessing Open Loop Geothermal Heat Pumps in Urban Areas

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ABSTRACT: The demand for renewal energy sources leads to an increase of open loop geothermal facilities. With the increasing amount of facilities, their cross-influence gets an important role. This paper describes the development of an instrument for assessing planned open loop geothermal heat facilities in the Limmat valley. The resulting tool is now in use at the cantonal government to facilitate the task of granting permits.

INTRODUCTION

In the last years, the cantonal government of Zurich was confronted with an increasing number of requests for the thermal use of shallow groundwater aquifers. Especially in the urban area of Zurich and the Limmat valley there have been realized a lot of new facilities. It became obvious that these facilities began to influence each other and the task of granting permits became difficult. The canton therefore decided to tender a decision tool based on regional numerical modeling.

PROJECT DECISIONS

The canton was aware of the complexity of the task. Its requirements requested that the calculation time should be less than one week. A budget for the training of the personnel was foreseen. To our opinion a calculation time of a week is far too long in a decision making process, taking into account that errors may happen which would double or triple this time. We therefore decided to choose a nested approach with a regional model containing the whole Limmat aquifer and local models containing only the planned facility and its neighbors. Because one cannot know where a new facility will be planned, the nesting had to be automated. Additionally we decided to eliminate the complex user interface of FEFLOW and provide the user with an easy to use interface that would make it difficult to make errors.

REGIONAL HEAT TRANSPORT MODEL

Situation

The Limmat valley covers an area of 36 km^2. The aquifer consists mainly of gravels deposited by the Limmat River after the latest glacial retreat. The gravel is underlain by lake sediments and moraines with a significantly lower permeability. The model restricts to the gravel aquifer with a permeability between $1x10^{-3}$ and $1x10^{-2}$ m/s. The aquifer is mainly fed by the Limmat River. Of minor importance are recharge through rainfall and lateral inflow. About 300 wells with a significant withdrawal had to be considered by the model.

Flow Model

A good flow model is a prerequisite for a correct heat transport model. To reach a high model reliability we performed a transient calibration and validation. A 2D model does sufficiently reproduce the Limmat aquifer. 106’000 groundwater level measurements were available since 2007. The calibration was done with the measurements of 2007 – 2009. The validation was done with the measurements of 2004 – 2006 and 2010. Separate 1D-models were built for the two rivers crossing the model. The resulting river stages enter in the groundwater model through Cauchy boundary conditions. The main challenge during calibration was supposed by the temporary wells used for construction works. At some periods the withdrawal of these wells exited that of the drinking water wells.

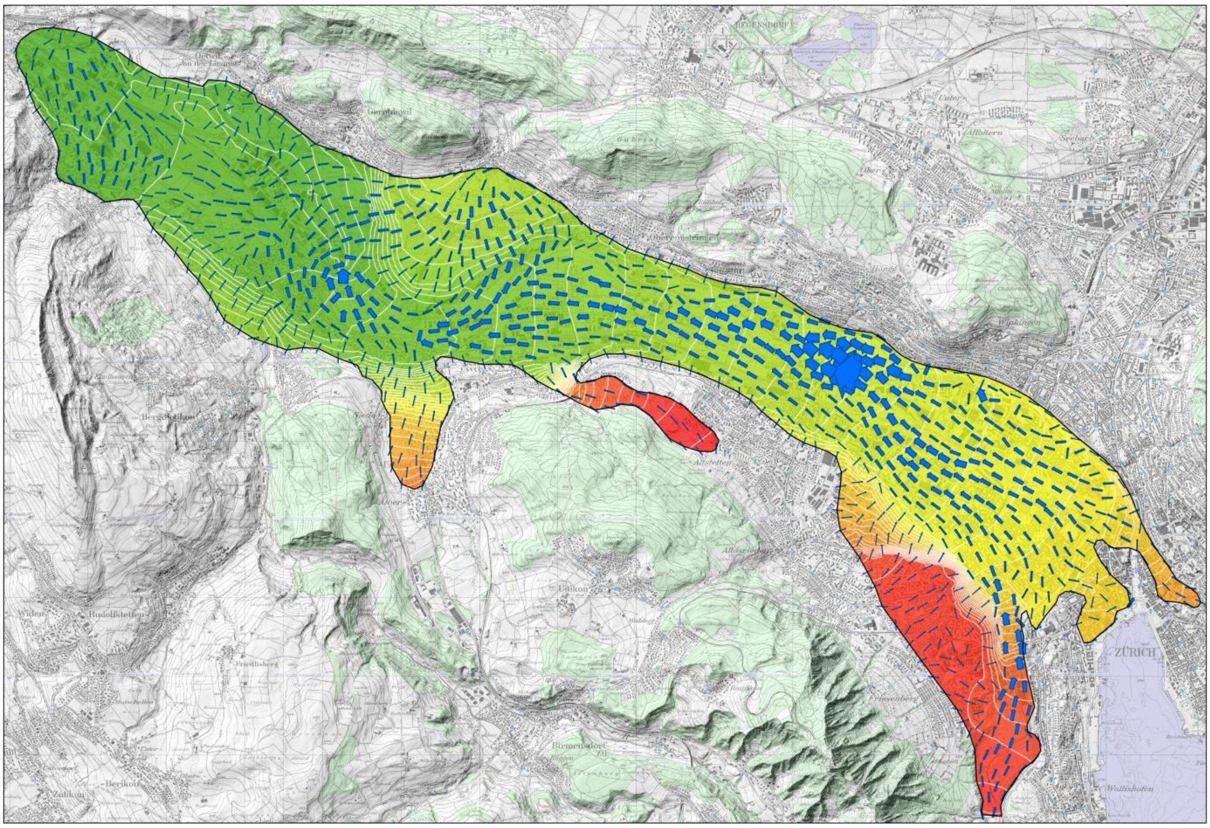

Figure 1: Head contour lines and Darcy velocities of the flow model.

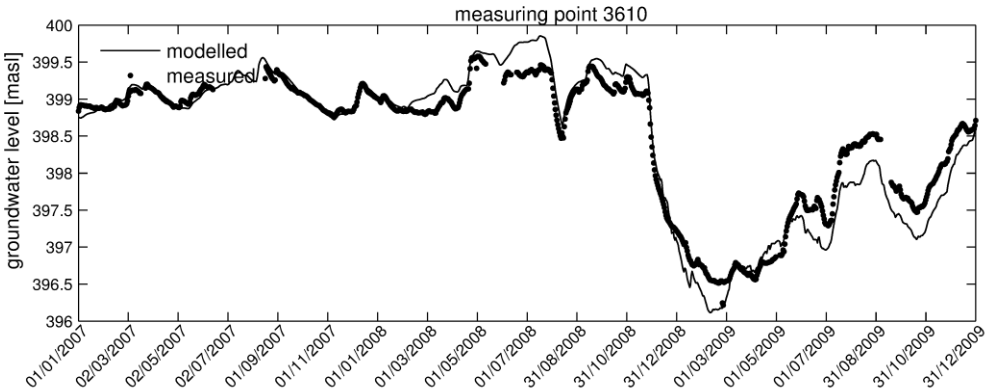

Figure 2: Calibration at a measuring point influenced by construction works.

Heat Transport Model

Based on the flow model, a heat transport model with a refined finite element mesh was built up. Preliminary studies showed that a 2D-model meets the requests of the client. For the heat exchange with the atmosphere however an IFM module hat to be prepared. It models the heat flow through the unsaturated phase with a 1D-linear expression. Another IFM module had to be prepared for the river boundary. The water entering from the river to the groundwater had to get the river temperature, while the groundwater leaving the aquifer to the river had to get the groundwater temperature.

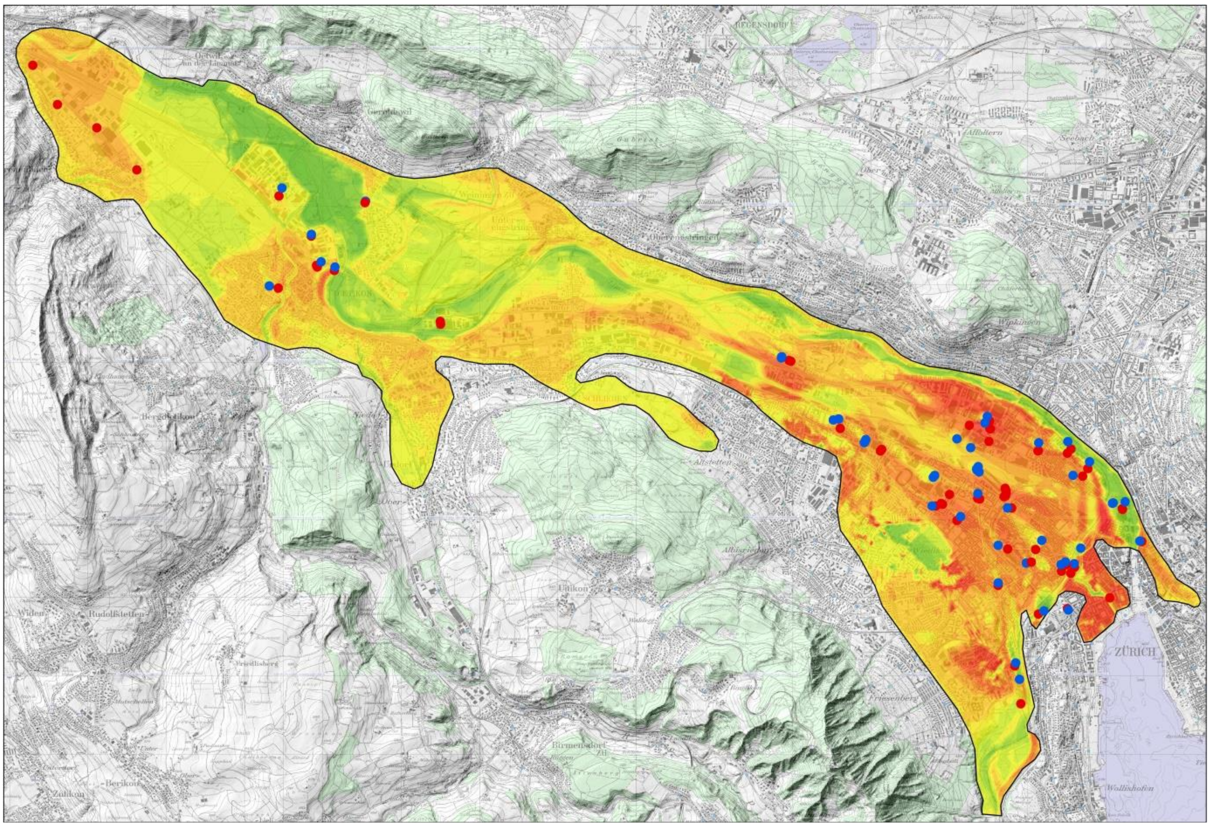

Figure 3: Open Loop facilities and calculated temperature field.

GEMTOOL

General architecture

The GEMTool application is realized as an internet application. FEFLOW is integrated as numerical engine to solve the flow and transport equations. The facility data is stored in a MySQL database. A number of modules in the Perl and C language are covering the tasks of generating the FEFLOW input file and creating visualizations from the FEFLOW output file. The user interface is realized in Java.

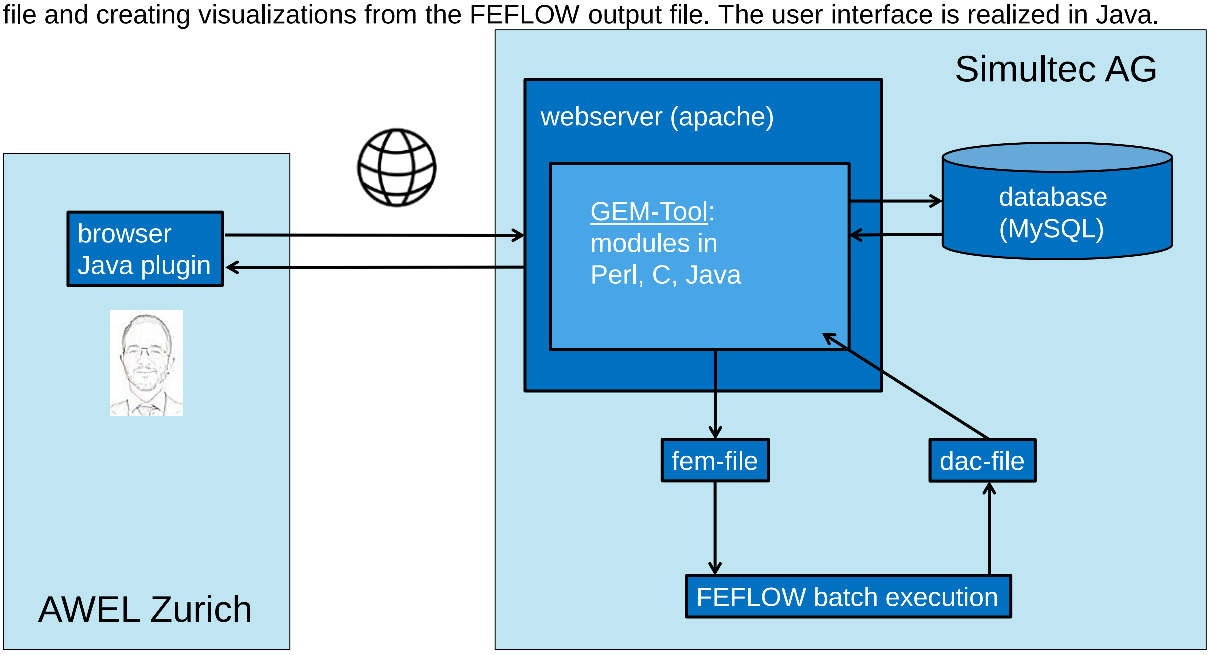

Figure 4: GEMTool application structure.

Model Nesting

The concept of the chosen model nesting is to provide a regional model with an approximation of the existing heat plumes and create a magnifying local model calculating the heat transport as accurate as possible. The nesting is a quite difficult technical task. After the definition of the withdrawal and infiltrating wells, the tool has to propose the boundaries of the local model. The decision is based on a flow path calculation and analytical estimates of the heat plume size. The model border can be defined manually as well. Once the border is defined, the GEMTool application creates a model mesh with the appropriate element size and refinement around the wells. The triangulation is done by the Triangle code (Shewchuk). The model parameters, boundary conditions and initial values are taken from the regional model.

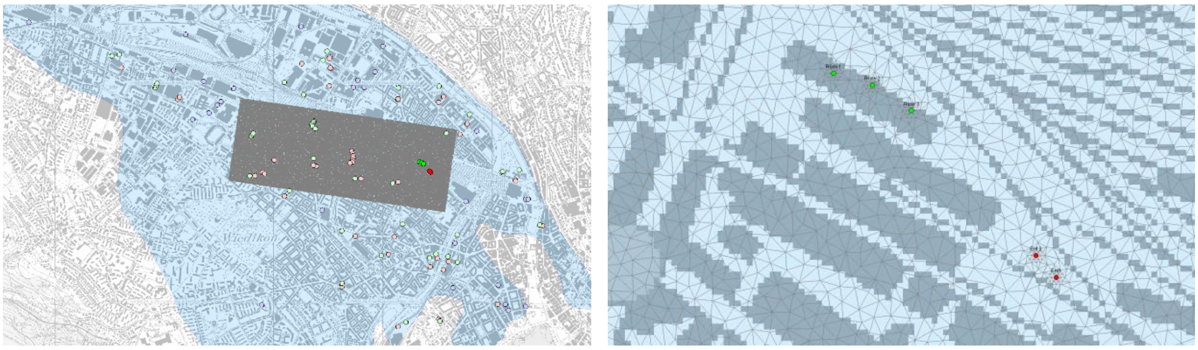

Figure 5: Model nesting and finite element grid of an example local model.

User Interface

The user interface is kept as simple as possible. It mainly consists of a map and a wizard guiding the user through the task of defining the facility and creating a model. After having finished the calculation, the user can create different visualizations and an automated report, telling him if the planned facility complies with the regulations. A particle tracking tool based on a continuous velocity field (Cordes and Kinzelbach 1992) and extended by a water balance method (Gmünder 2009) facilitates the determination of back coupling.

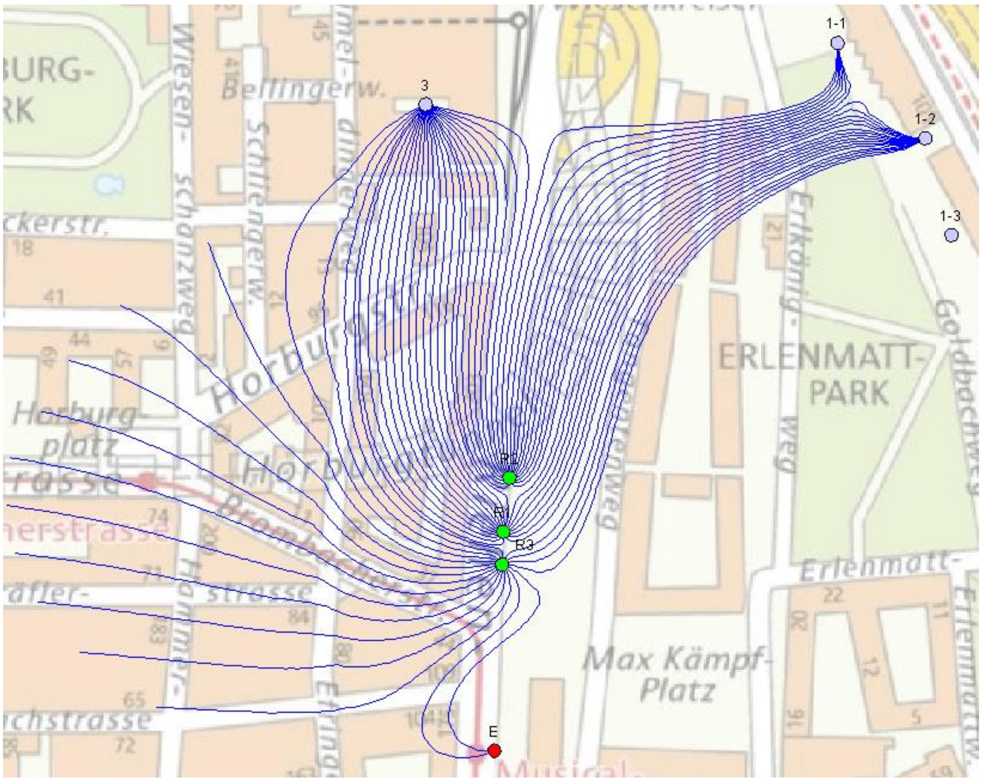

Figure 6: Back coupling calculation with the particle tracking code developed by Simultec AG.

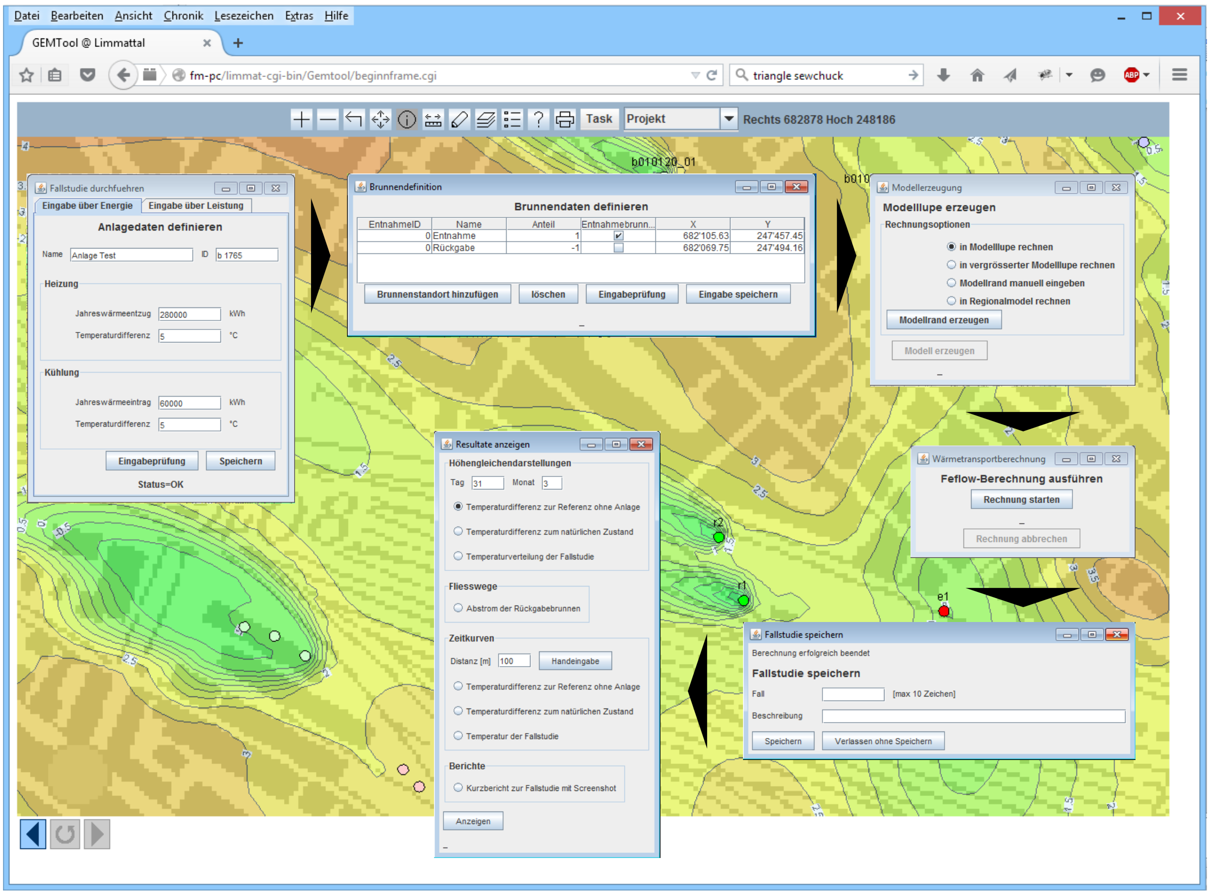

Figure 7: Graphical user interface with workflow for a model calculation

APPLICATION EXAMPLES

The GEMTool application was installed on a server at Simultec AG in 2014. The application is used by the canton Zurich in the approval procedure for open loop facilities. The execution of a model calculation does require about two hours.

The tool turned out as very helpful for consulting tasks and it was applied to other aquifers in the Thur valley, Winterthur, Schaffhausen, Basel and Suhr. Once a regional model is built up, it is very easy to create local models and to test different well positions. Even for creating local transport models, the tool is helpful. Further development will therefore be done in this direction.

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