INFLUENCE OF WATER ABSTRACTION ON THE GROUNDWATER FLOW IN BAB

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Introduction

The groundwater is the main source of drinking water in the Baltic States, it is used also by industry and agriculture. Despite of huge groundwater resources, sustainable operation of large water extraction objects or regions are possible only considering the response of the groundwater system, i.e. considerable reduction of groundwater level.

The most essential part is the data collection and analysis – without the knowledge of the amount and spatial distribution of water extraction it is impossible to gain understanding of groundwater flows and the usable groundwater resources.

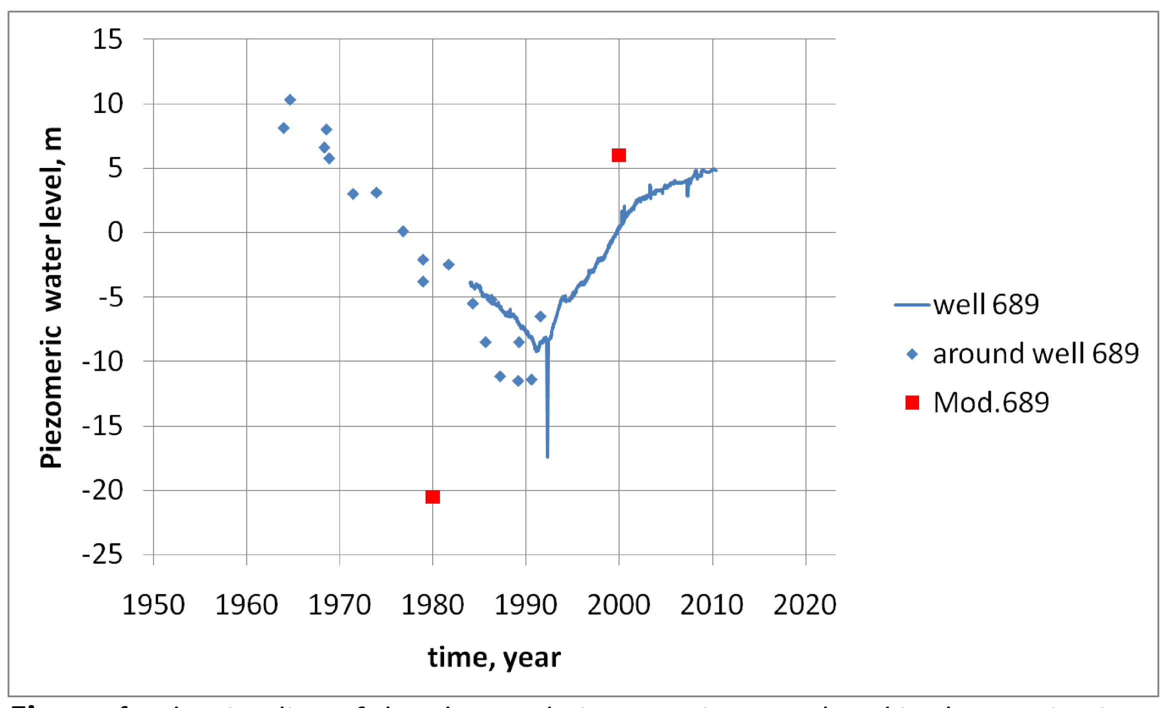


Figure 1: *The timeline of the observed piezometric water head in the monitoring well No.689 (line) and measured levels during installation of wells in 4 km radius around well No 689 (blue dots) near Jelgava with filter situated in aquifer Devonian Gauja (D3gj). The points Mod.689 correspond to the modelled results of the situation in year 1980 and 2000.*

Three different scenarios of groundwater abstraction

There are 3 different scenarios of groundwater abstraction trends in the region of Baltic Artesian Basin starting with year 1950 until nowadays:

1. Natural scenario of groundwater abstraction – minimal water extraction, nearly unnoticeable comparing with natural processes of water circulation;
2. Wasteful scenario of groundwater abstraction – significant water usage leading to reveal influence to the groundwater resources;
3. Medium scenario of groundwater abstraction – reasonable water extraction, minimal influence to the groundwater resources maintaining the natural groundwater resource restoration.

The trend of groundwater extraction in all Baltic countries is similar – starting with year 1950 until approximately year 1965 the representative trend is minimal water extraction (natural scenario of groundwater extraction); from year 1965 until year 1990 the characteristic trend is the increasing amount of groundwater extraction, which leads to wasteful scenario of groundwater extraction at the end of the given time period; after the year 1990 there is observed a rapid decrease in amount of extracted groundwater referring to the medium scenario of groundwater extraction at nowadays.

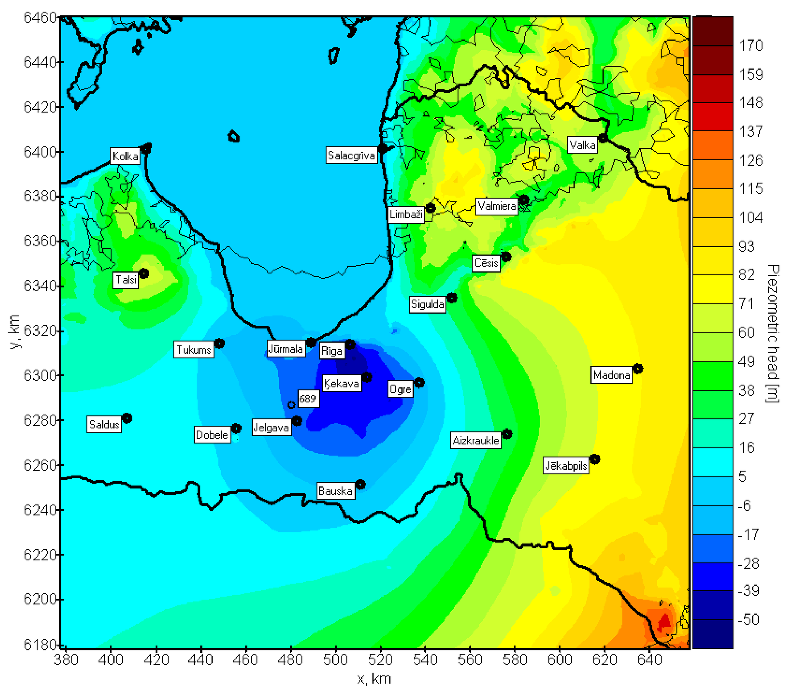
A timeline of observed piezometric water level in the monitoring well No.689 of the Upper Devonian Gauja aquifer (D3gj) has been shown in Fig. 1. The rapid decrease of the water level in the observing well in the time interval from year 1982 until 1990 has to be proportional to the increasing amount of a nearby water extraction wells; the well No.689 is located near city Jelgava and by the growth of industrial regions of the city the water demand had increased. After the historical events in year 1990 and the closing of the most of the industrial factories the water level in the monitoring well increases what refers to the groundwater resource restoration. As the well No.689 gives no data before year 1982, the water levels measured during the installation of wells in 4 km radius around the well No.689 are shown, too.

Methods and input data

The modelling is performed on the hydrogeological model of Baltic Artesian Basin version 1 with calibrated properties of the infiltration parameter and the vertical and horizontal hydraulic conductivities of each geological horizon built into the model. The calibration is carried out using the observed piezometric levels from the monitoring wells as well as the water level measurements during the borehole creation therefore leading the calibrated model to characterise the observed situation in year 2000 which closely refers to nowadays.

To get more precise distribution of piezometric water head the distributions of precipitation, evapotranspiration, runoff and groundwater runoff from the regional climate models are used instead of constant infiltration parameter. The distribution of water infiltration from surface into the deeper horizons is calculated using these data.

The known water abstraction data in year 1980 and 2000 is used as the input data for this research. Two stationary calculations with different water abstraction amounts are performed using the program of MOSYS script. The results of calculations are visualized using program HiFiGeo and after that compared with the given observed piezometric water levels from the well database.



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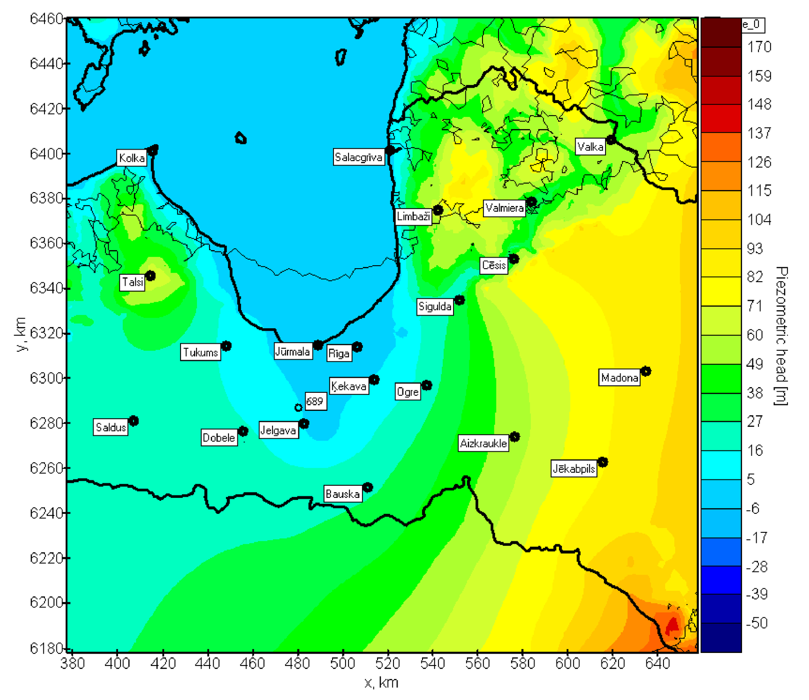

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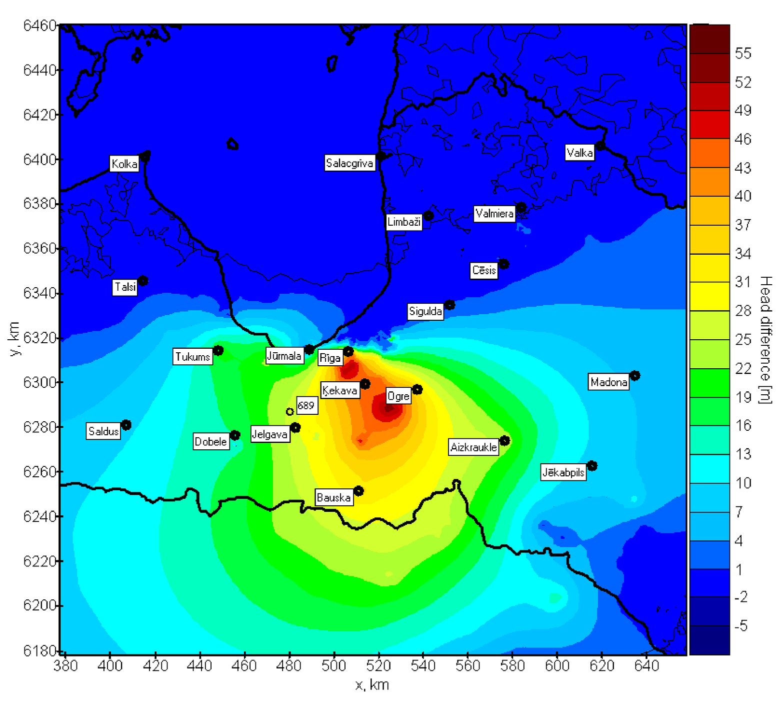

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Figure 2:

A *The distribution of piezometric water head in the aquifer Devonian Gauja (D3gj) modelled by using the information about water abstraction in year 1980. The dark blue area shows the cone of depression.*
The thin black line defines the prevalence area of the aquifer; the thick black line defines the political borders of countries.

B *The distribution of piezometric water head in the aquifer Devonian Gauja (D3gj) modelled using the information about water abstraction in year 2000.*

C *The distribution of piezometric water head difference where the distribution in picture A has been compared with distribution in picture B. The red colored area corresponds to the situation when the piezometric level in year 2000 is higher than in year 1980 or the former places of the increased water extraction.*

Results

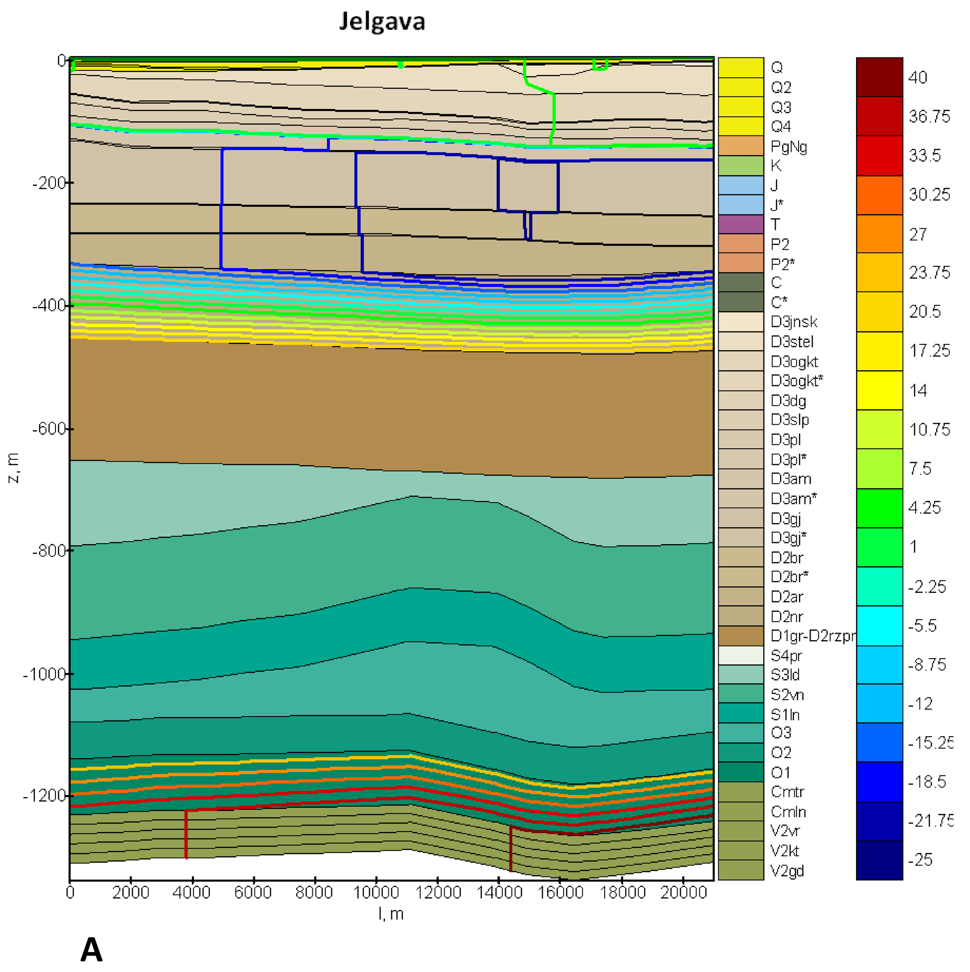
The stationary calculations using the hydrogeological model of BAB version 1 approves that the increased groundwater extraction causes distinct areas of depression. In Latvia the cones of depression are observed in the aquifers Upper Devonian Gauja (D3gj), Upper Devonian Amata (D3am), Middle Devonian Burtnieks (D2br) near Riga as well as in the Cambrian aquifer in Estonia near Tallinn in the case of medium and wasteful scenario of groundwater abstraction.

Let us take a look at the example of a typical cone of depression in the aquifer D3gj in central Latvia shown in the figure 2. The usual non-homogeneous water abstraction well distribution throughout the BAB leads to the existence of the limitation of the groundwater usage. If the limit is exceeded the regions with lower piezometric water level are formed comparing to the case without any water extraction. It should be noticed that the calculations are carried out for the stationary process but, as shows the figure 1, the water extraction changes over time. Therefore so low piezometric levels were not observed in reality, as the result of a stationary calculation shows the possible water level distribution if the water extraction would remain the same for infinite long time.

In figure 2-A the predicted distribution of water levels in case of wasteful scenario of groundwater abstraction is shown.

As the medium scenario of groundwater abstraction there stands figure 2-B where the small cone of depression in the area near Riga can be seen, where the level is not lower that the sea level. It is obvious that the groundwater flows in medium scenario are closer to the undisturbed natural state than the wasteful scenario in figure 2-A.

The historical change in the water abstraction distribution from year 1980 to year 2000 is seen in figure 2-C.



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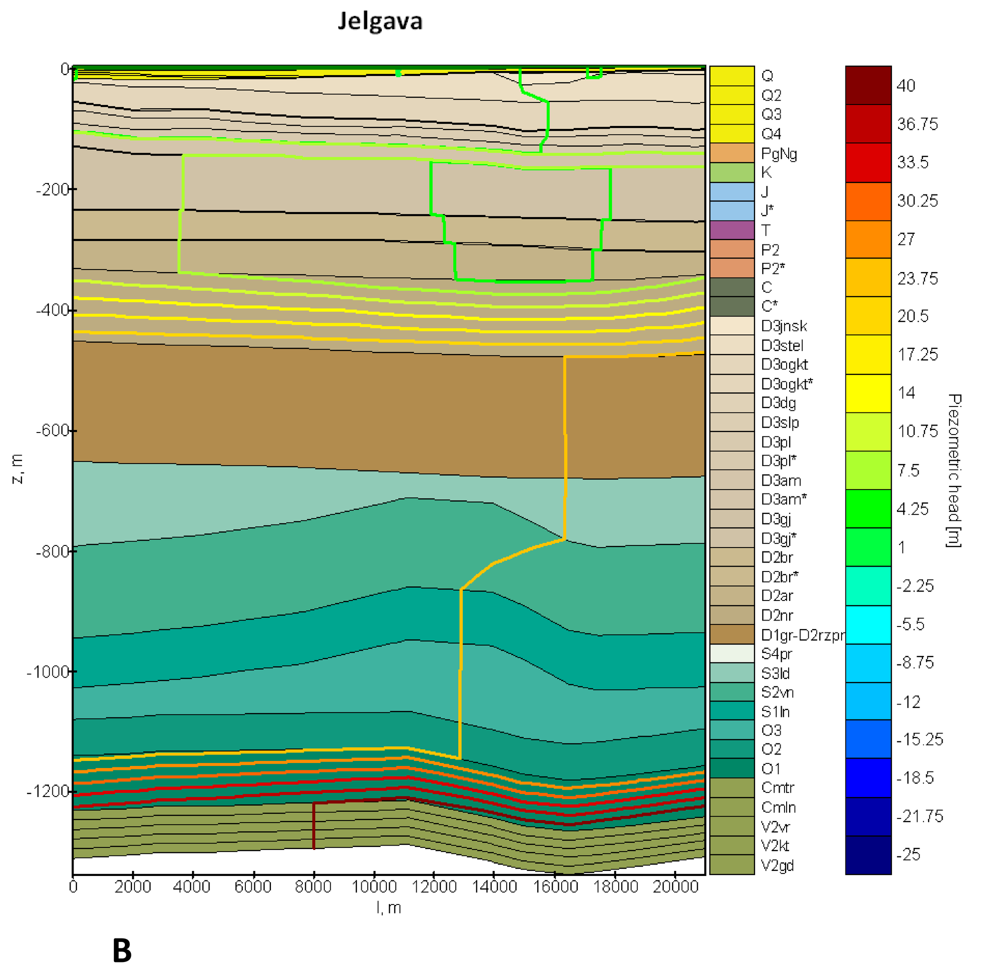

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Figure 3:

A *The vertical cross-section near city Jelgava. Colored lines depict the modelled piezometric water head of the situation in year 1980. The blue area shows the significant amount of water extraction.*

B *The vertical crossection near city Jelgava. Colored lines depict the modelled piezometric water head of the situation in year 2000. The green area shows the mild amount of water extraction.*

For better understanding of the influence of water abstraction on the groundwater flow it is useful to compare the both results in the view of vertical cross-section. The figure 3 gives an example of a vertical cross-section near city Jelgava.

There is a significant water abstraction in aquifer D3gj influencing the layers close to the mentioned aquifer like D2br and D2ar forming an aquifer system. With the long term water abstraction it may lead to the rapid decrease of piezometric water level in the area marked by dark blue lines. Comparing the piezometric water level in the mentioned aquifer system with the piezometric water level in the lower aquifer separated by one aquitard, the head difference is about 40 m in the wasteful scenario of groundwater abstraction.

In the case of picture 3-B there is practically negligible influence of water extraction to the groundwater flows (the groundwater flows from the area with higher piezometric water level to the area with lower piezometric water level). The difference of piezometric water level between the previous mentioned aquifer system and the aquifer separated by one aquitard in the model is about 10 m which is at least 4 times less than in the situation of the wasteful scenario of groundwater abstraction.

Figure 3 also shows, that the water abstraction on shallow layers has no influence on the groundwater flows in the deeper horizons of BAB.

Conclusions

The groundwater extraction sources have non-homogeneous distribution throughout the Baltic Artesian Basin where the most of the wells are concentrated around the biggest cities and industrial regions (in the territory of Latvia it refers to the largest cities: Riga, Liepaja, Daugavpils, Jurmala etc.). The spatial localization of groundwater wells leads to the vulnerability of the local groundwater resources as well as the limitation of groundwater resource usage.

The preferred future mode of groundwater extraction should maintain the balance between the extraction and restoration of groundwater resources. In the cases of necessary increase of groundwater extraction amount there one must consider the influence of the potentially available groundwater resources.

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