Groundwater modelling of the South lignite field, West Macedonia, Greece

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Abstract: For the protection of the South Field open pit mine, of Ptolemais basin, from the intrusion of groundwater, the aquifer, which lies above the lignite layer and consists of neogene and quaternary sediments, is being drained by wells and by surface pumping stations. Extensive groundwater quantities are also being pumped from the same aquifer for domestic, agricultural and industrial use along the South field basin. The overpumping has created a negative aquatic balance resulting in a continued decrease in groundwater level. For the investigation of the environmental impacts on the area, a groundwater model was created.

The groundwater model of the South lignite field has shown that the water table around the mining area will continue to decrease. This decrease is caused by the increased volume of pumped groundwater quantities for the protection of mine. The general decrease in water table in the whole area of South field basin, though, is due to overpumping for domestic, agricultural and industrial use.

1 INTRODUCTION

Extensive groundwater quantities are being pumped from the South field of Ptolemais basin for the dewatering of the South field open pit lignite mine, for domestic, agricultural and industrial use. To investigate the environmental impacts on the area, a groundwater model was created. The simulation took place with the numerical groundwater modeling code of Rheinbraun Engineering GW3D V3.0[(5)].

2 TECHNICAL CHARACTERISTICS OF THE MODEL

2.1 Existing aquifers in South field basin

The aquifers in the South field basin are the following :

a) in neogene and quaternary sediments, which lies above the lignite layer and appears almost in the entire area of the basin (Figure 1).
b) in jurassic limestones at the eastern and western boundaries of the basin.

c) in cretaceous limestones at the southern boundaries of the basin (the area around the Drepano village).
d) in neogene sediments which lies below the lignite layer.

The aquifer that influences the mine and is exploited by the pumping wells is the one of neogene and quartenary sediments and lies above the lignite layer. This is the aquifer that was simulated.

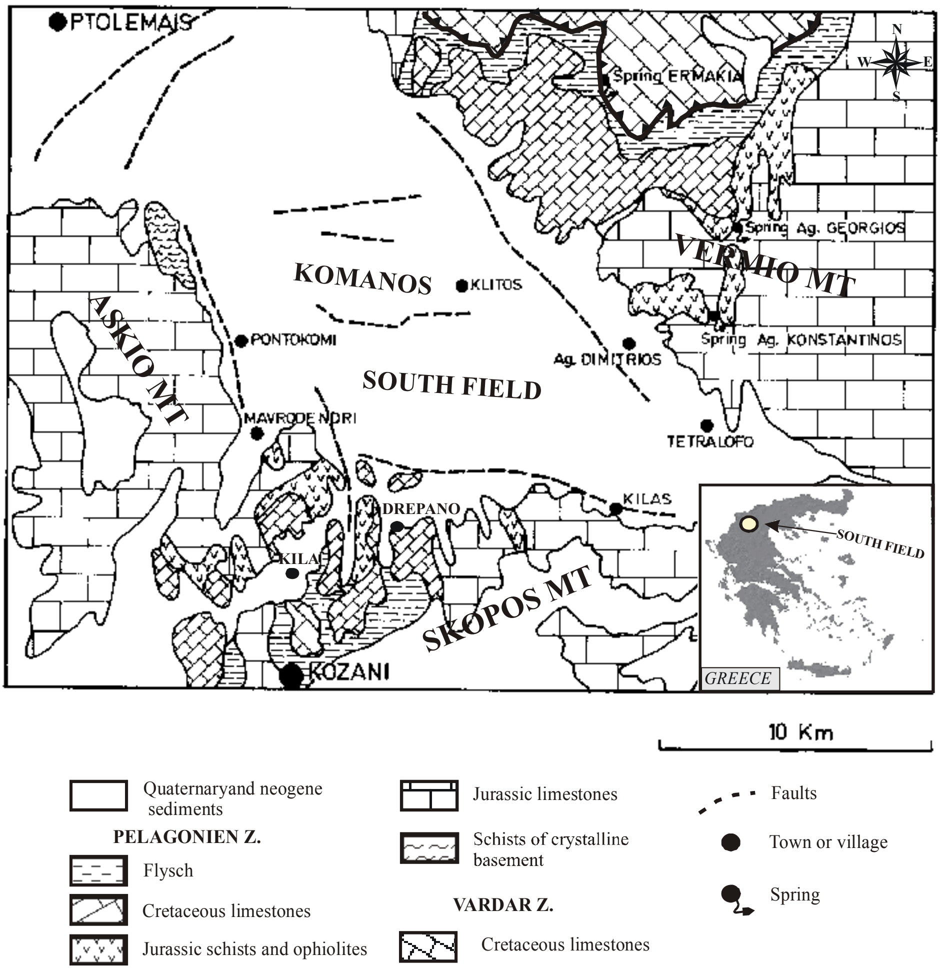


Figure 1 Geological map of South field basin

2.2 Boundaries of the model

The first step for the construction of a groundwater model is to decide about the extension of the area of interest and set its boundaries. In the case of South field we accepted as boundaries the contact of neogene and quaternary sediments with the karstic formations at the edge of the basin. The boundaries of the model are the following (Figure 2):

a) Eastern and northeastern: the contact of the neogene sediments with the jurassic limestones of Vermio mountain, (constant inflow boundary).
b) Western: the contact of the neogene sediments with the jurassic limestones (constant inflow) and the schists of Askio mountain (no flow boundary).
c) Northwestern: we accepted as no flow boundary the tectonic horn, which actually prevents the hydraulic connection between the South field basin and the area of Komanos mine.
d) Southwestern: the contact of the neogene sentiments with the karstic formations of Skopos mountain is a constant inflow boundary.
e) Southeastern: we accepted as boundaries the area where the thickness of the neogene sediments is dwindled due to the erection of the crystalline basement (outflow boundary).

The area of simulation is 120 $x10^6$ m^2.

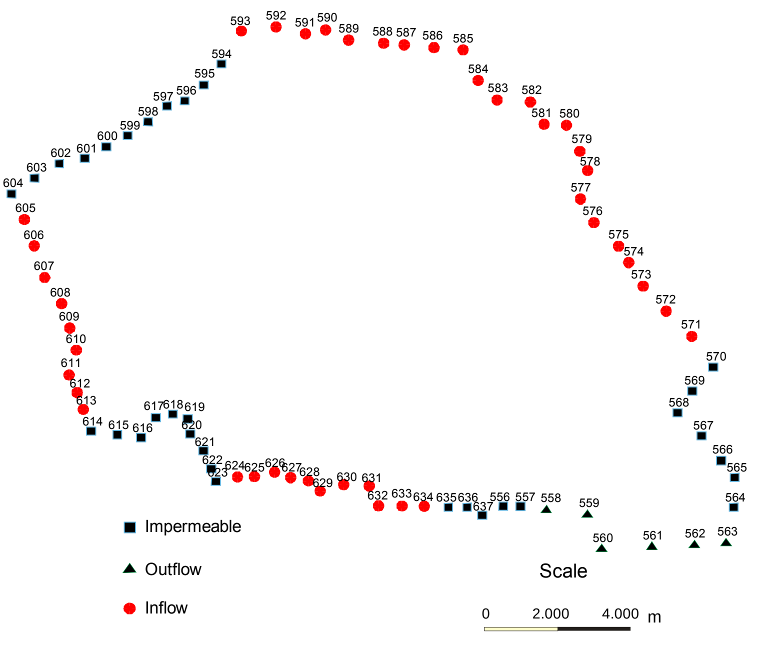


Figure 2 Boundaries of the model

2.3 Time-steps

The simulation starts at 1990 (initial conditions). The duration of each time–step is one year for the period between 1990-2006 and two years for the period between 2006-2020.

2.4 Construction of the triangular grid

A very important step in modeling is the construction of a representative grid, based on the amount of the available data and the areas of major interest. The grid that it was constructed was triangular.

The length of the triangle's sides was:

- between 800-1000 m in the areas where precision is not required and there was a lack of data,
- up to 300 m in the areas of major interest, around water supply wells or the mining area, where the available data is sufficient.

2.5 Aquifer's hydrogeological characteristics

2.5.1 Geometrical characteristics

In order to estimate the expansion of the aquifer along the South field basin, its thickness, the altitude of its top and bottom, longitudinal and transversal geological sections were constructed.

2.5.2 Piezometric - initial conditions

For the construction of the piezometric maps, measurements of the groundwater level, in specific wells along the basin, were used. The measurements took place in 1996-1999. These maps were used for the calibration of the model. Measurements of the year 1990 were used as initial conditions.

2.5.3 Inflow-outflow

- Recharge

After the statistical analysis of the meteorological data we estimated the average yearly rainfall at 600 mm. Considering infiltration 10-12% of rainfall, we took:

a) an average infiltration at nodes which are located at the alluvial equal to 2.6 $lt/s*km^2$,

b) an average infiltration at nodes at the conglomerates equal to 3.1 $lt/s*km^2$.

- Domestic and agricultural groundwater quantities

The groundwater pumped out for agricultural use in 1990 (initial conditions) was approximately $10x10^6$ m^3/year. Groundwater quantities for domestic use were estimated at $3x10^6$ m^3/year.

2.5.4 Hydraulic conductivity

The hydraulic conductivity of the aquifer was calculated with pumping tests in 30 wells around the basin. Its value varies between 100-1200 m^2/day with increasing values from northeast to southwest.

2.6 South field mining plan

The calibration of the model required the depiction of the benches and slopes of the mine at the specified time-steps. The depiction of the internal dump (extension, altitude of its bottom and its height) was also required.

Simplified conditions

In order to depict, in model's code, the advance of the mine excavation and the internal dump in each time-step, we accepted an average stage of their position (Figure 3).

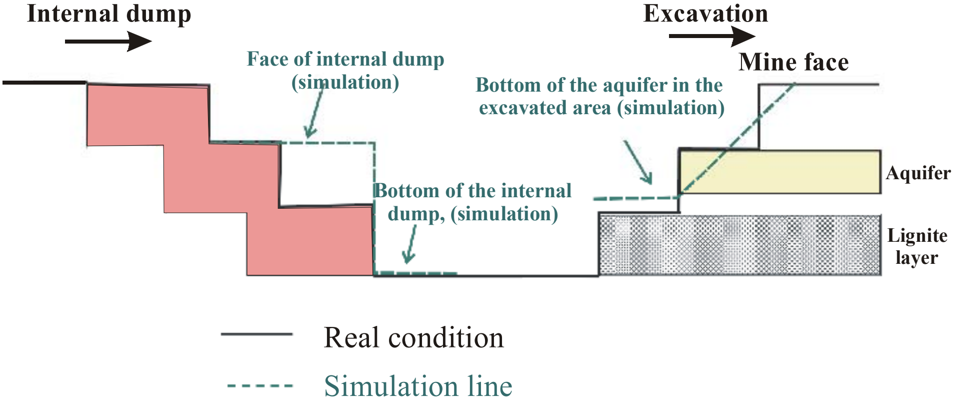


Figure 3 Simulation lines and real condition of mine face and internal dump.

2.7 South field dewatering plan

The dewatering plan of the mine is depicted in diagram 1. Diagram 2 resulted from the total pumping groundwater quantities for domestic, agricultural and dewatering use, along the basin. The observed fluctuations on the values at the successive time-steps (diagram 1) are due to the mathematical simulation and give a rough estimation of the pumping quantities. The constant line smoothes out the differences and gives more realistic values of the pumping quantities.

3. RESULTS OF THE SIMULATION-CONCLUSIONS

The results and conclusions of the simulation for the years 1999, 2001 and 2005, are the following.

3.1. Changes on the piezometric surface

- Initial piezometric conditions, flow conditions in 1990 (time-step1). From the position and shape of the piezometric lines it can be concluded that the

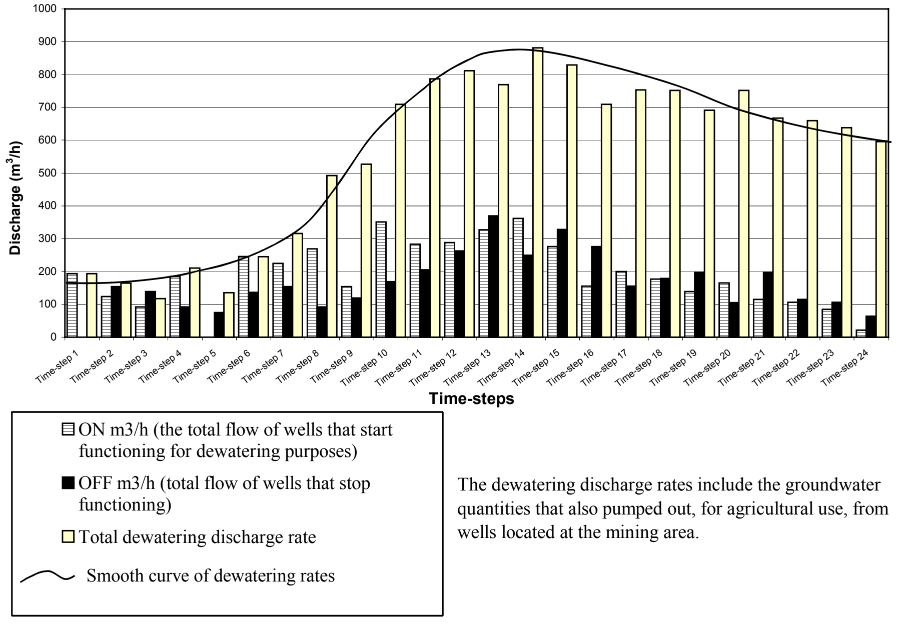


Diagram 1 Rates of discharge from dewatering wells.

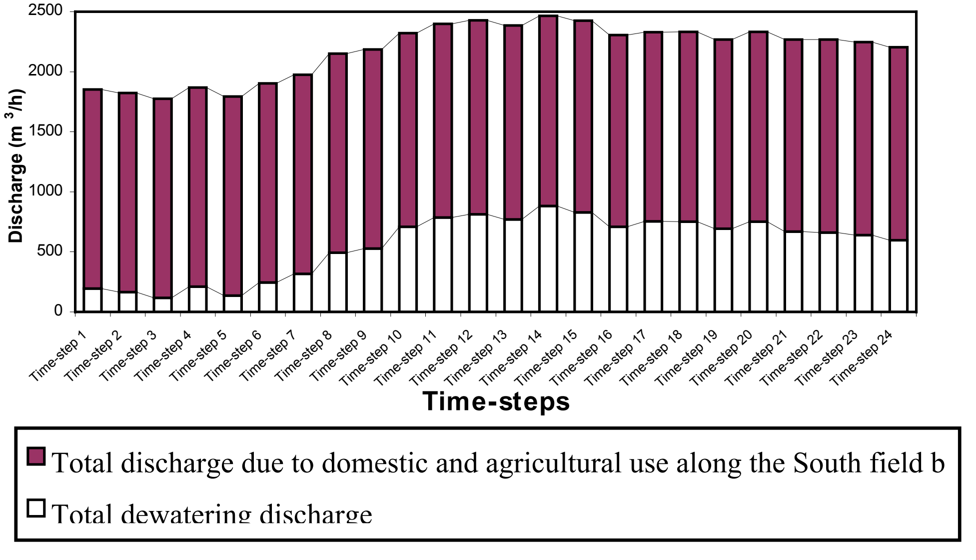


Diagram 2 Total discharge for domestic-agricultural use along the basin and for the dewatering of the mine.

mining works on the South field open pit mine had not affected the piezometric surface of the aquifer in the long distance area. This is due to the fact that no systematic dewatering pumps had started at that time (Figure 4).

Due to the lack of piezometric measurements of the groundwater level at the boundaries of the basin, a theoretical estimation of the water level in these areas was used, based on the general hydrogeological knowledge on these areas. Today, recent measurements in these areas have confirmed the initial conception.

The general direction of the flow is from northeastern to central and southern area of the basin. A flow directed from western to central area also occurs.

An inflow from the cretaceous limestones to the aquifer takes place in the southwestern boundaries (Kila-Drepano area) of the basin. An outflow from the aquifer to the external system also takes place in the southeastern boundaries of the basin (Kilas area).

- Flow conditions in 1999 (time-step 9). The advance of the mine face and the internal dump is depicted in figure 5. The nodes that represent the mining area appear to be "dry".

The piezometric lines appear dense at the eastern boundaries of the mining area due to the dewatering process. There is still no evidence of a large-scale effect on the piezometric surface of the basin due to the dewatering process.

However, a small decline of the groundwater table appears along the basin due to the large number of pumping wells, scatter all over the basin, for agricultural and domestic use.

- Flow conditions in 2001(time-step 11). The piezometric lines along the basin appear to be in a lower lever than those of 1999 (Figure 6). This decrease in groundwater level is evidence of a negative aquatic balance.

A maximum 10 m decrease of the groundwater level is appeared in the proximity of the mining area due to the dewatering process. The dewatering process seems to have an insignificant impact in the area further from the mine.

- Flow conditions in 2005 (time-step 15). At that time the piezometric lines appear to be even lower (Figure 7).

The dewatering discharge rate is approximately 850 m^3/h. A cone of depression appears around the mining area. Piezometric lines to the southern boundary of the basin shows an increased influence of the pumping for agricultural, domestic and dewatering use on the piezometric surface on this direction.

The piezometric line of +640m at the northeastern boundaries has been drawn back, approximately 300-400 m, even in areas 7-9 Km away of the mining area. That fact indicates that apart from the dewatering influence, the basin is generally in a negative balance.

In the area of pumping wells for domestic use, a decrease in the water level of 5-10 m is appeared. The place of the +640 m piezometric line in 2001 has been taken by line +630 m. That fact indicates a more permanent impact on the aquatic balance of the basin.

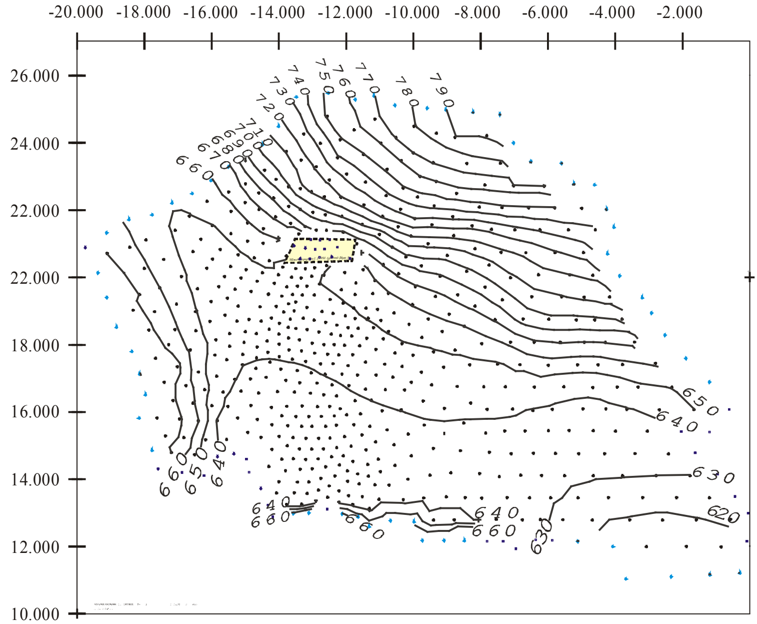
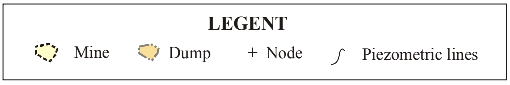


Figure 4 : Piezometric lines of simulation 1.1.1991, time-step 1



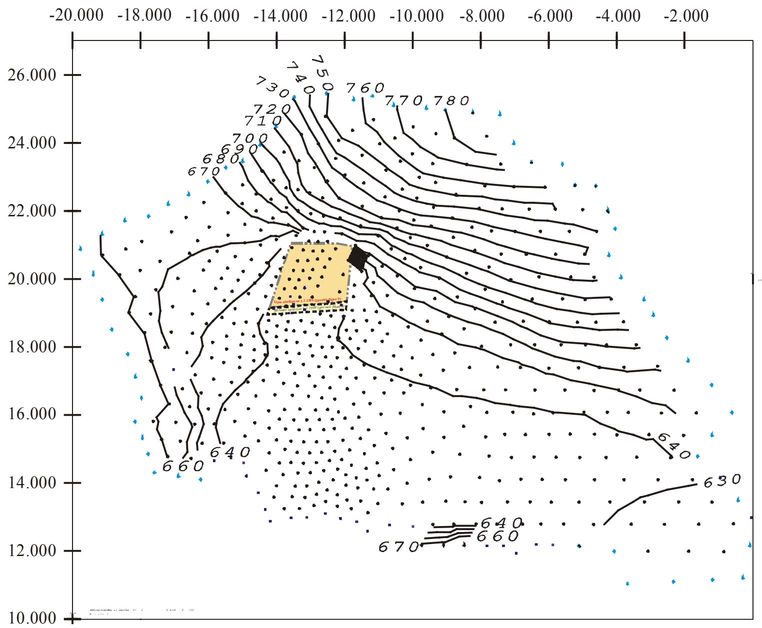


Figure 5: Piezometric lines of simulation 1.1.1999, time-step 9

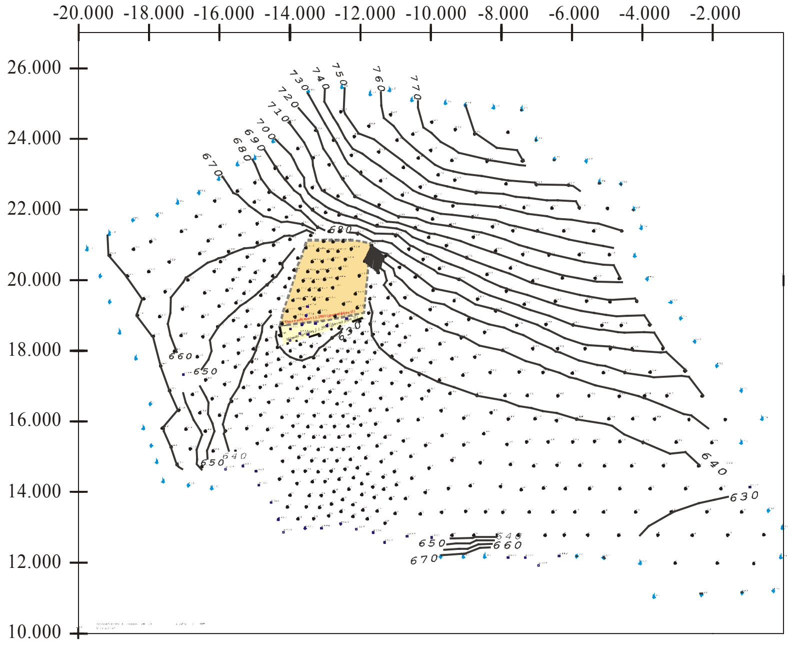
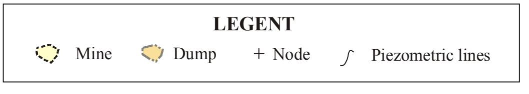


Figure 6 : Piezometric lines of simulation 1.1.2001, time-step 11



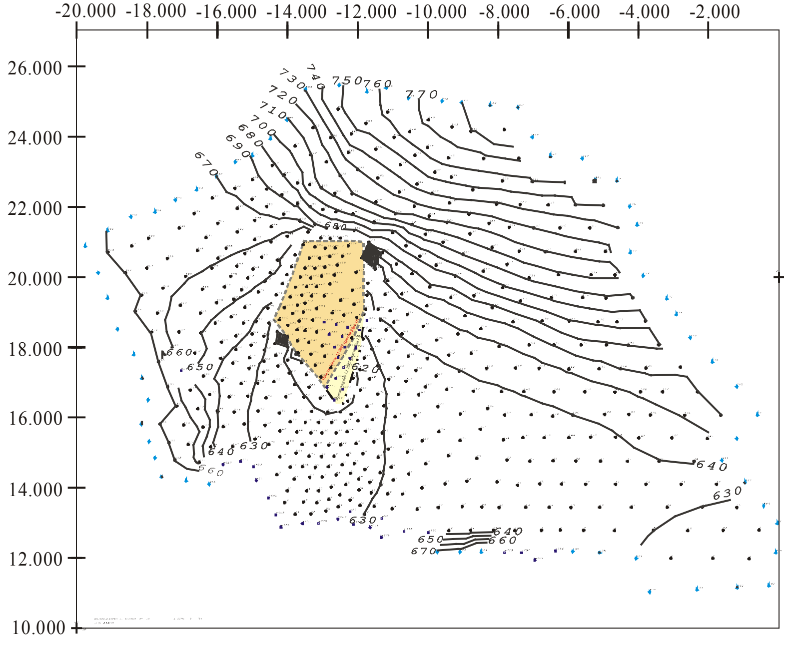


Figure 7 :Piezometric lines of simulation 1.1.2005, time-step 15

3.2 CONCLUSIONS

The groundwater model resulted in an estimated dewatering discharge rate for 1999 700m^3/h, which approaches the real discharge rate of 750 m^3/h. The difference is due to the fact that the previous years smaller than the required quantities were pumped for the dewatering of the mine. In order to cover the required quantities that had not been pumped at the previous years, increased quantities had to be pumped in 1999.

According to the simulation the pumping rates have to be increased up to 850-900 m^3/h (time-steps 11-15). The discharge will start to dwindle at time-step 16 and will reach the value of 600 m^3/h at time-step 24.

The estimated piezometric lines of 1999 approach the piezometric lines that were designed based on site measurements of the piezometric surface. So, the simulation of the aquifer is regarded as satisfactory.

However, the efforts for a better adjustment of the model should continue since there are areas where the available data are very poor, especially those regarding the groundwater level.

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Modelowanie wód podziemnych w południowym polu złoża lignitu, Zachodnia Macedonia, Grecja

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Streszczenie: Dla ochrony południowego pola kopalni odkrywkowej przed wdarciem się wód podziemnych, zbiornik wód podziemnych leżący powyżej złoża lignitu i składający się z osadów neogenu i czwartorzędu, jest drenowany systemem studni i odwadniania powierzchniowego. Duże ilości wód podziemnych są także pompowane wzdłuż południowego pola dla użytkowania w gospodarstwach, rolnictwie i przemyśle. Nadmierne pompowanie spowodowało zachwianie równowagi wodnej, co przyczyniło się do ciągłego obniżania poziomu wód podziemnych. Dla zbadania wpływu drenażu na środowisko w tym rejonie stworzono model wód podziemnych. Model wód podziemnych południowego złoża lignitu wykazał, że zwierciadło wody wokół kopalni będzie się stopniowo obniżało. Obniżenie to jest spowodowane zwiększoną objętością wody pompowanej w celu zabezpieczenia eksploatacji górniczej. Jednakże, ogólne obniżenie zwierciadła wody wzdłuż pola południowego, jest wynikiem nadmiernego pompowania wody na potrzeby gospodarstw, rolnictwa i przemysłu.