Modelling of the Future „Piaski" Open Pit Impact on the Water Environment

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Abstract

The dewatering operation in the "Piaski" open-pit is planned from 2008 and it will be finished in 2036. The dewatering well barriers system will be applied. Based on the quasi 3D two-layered numerical model with area of 1550 km^2, groundwater flow system for premining and mining conditions using MODFLOW was constructed. Except the time of dewatering, the most important factors deciding on the range of the cone of depression are increase of effective infiltration, specific yield and storativity. These factors can't be estimated based on the premining model, so it is necessary to use reliable data from other areas of mine operations.

Key words: open pit dewatering, modelling, environment, Poland

Introduction

The lignite open pit „Piaski" will be another pit of the lignite mine „Konin" S.A. Overburden stripping is planned to start in 2010 in the north part of the lignite field and mining operation will advance in the southern part. The lignite production capacity will be approximately 3.5 million tons per year and it will be finished in 2036. For the mine dewatering an external and internal barrier of wells will be constructed. The depth of the wells will vary between 60 and 90 m. The groundwater level will be lowered within the deposit area and the maximum depression will reach from 30 to 60 m. The water from the drainage system will be discharged to the Warta river by pipelines, ditches and channels.

Location and hydrology condition

The lignite deposit „Piaski" is located in the north part of the lowland „Nizina Wielkopolska", between Prosna and Warta river (figure 1). The ordinates of the land are 85 to 110 m a.s.l. and they lower to the north, towards the Warta river. The average annual precipitation amounts to approximately 550 mm and the land evaporation is 471 mm. Within the area of the deposit, the hydrological system is poorly developed and its principal element is the left-bank tributary of the Warta river – namely Czarna Struga, whose catchment covers approximately 95% of the deposit.

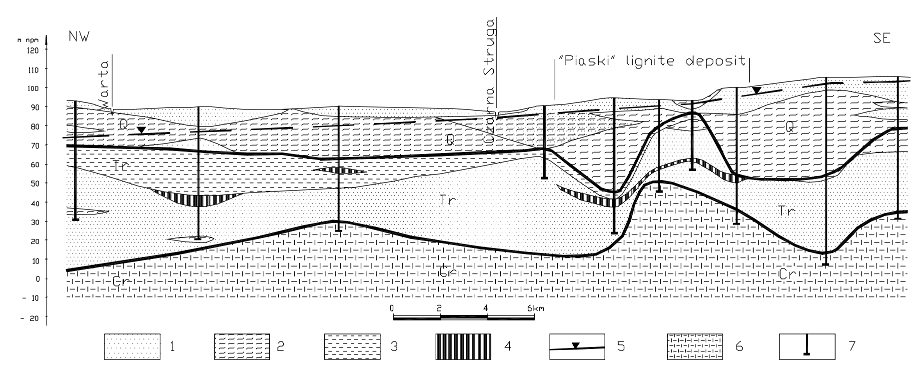
Geological and hydrogeological condtitions

The region of the deposit lies in the South-West part of the basin called Niecka Mogileńsko-Łódzka, whose roof is formed by upper cretaceous sediments (figure 1). Taking into account the dewatering conditions, three aquifers have been determined within this area: quaternary and tertiary overburden aquifer, tertiary lignite underlying aquifer and cretaceous aquifer.

The overburden aquifer creates the tertiary and quaternary sandy formations lying over the lignite seam. The permeability coefficients are 2.54 m/d to 10.42 m/d, the average being 5.93 m/d, and the specific yield is 0.1 to 0.13 (Dziedziak 1996). The groundwater are recharge directly from precipitations. The groundwater level within the region of the deposit is from 80 to 100 m a.s.l. The groundwater flow direction is determined by the rivers.

Directly beneath the lignite seam the tertiary fine and medium-sized sands occur lying on the silts and mudstones, or directly on the cretaceous formations. Their thickness is 6 to 21 m, the average being 12 m. The permeability coefficients are 0.79 m/d to 16.75 m/d, the average being 6.67 m/d; the storativity is 0.000491 to 0.002, while the specific yield is 0.14. The cretaceous aquifer is represented by marls, sometimes with mudstone layers. Those formations, due to the existent fracture and interstices, create an aquifer which is used by the water intakes. The average permeability coefficient is 3.82 m/d, while the storativity is 0.00368. Slight isolation and sometimes lack of isolation between the cretaceous and tertiary lignite underlying aquifer, enable hydraulic contacts between these aquifers, which is provided by similar the water table level and the low variability of chemical composition. The aquifers are recharged by leakage of water from the quaternary aquifer or directly through the hydrogeological windows. The groundwater level is some meters higher than in the overburden aquifer. The general groundwater flow directions are towards the Warta river on the north and towards the Prosna river on the west of the area. The quaternary and cretaceous aquifers on the north and west of the future open pit belong to the Major Groundwater Basins no 150 and no 151 (Kleczkowski 1990).

Figure 1 *The hydrogeological cross-section through the "Piaski" deposit area (A–A'). Explanations: 1 – fine and medium sands; 2 – clays; 3 – silts; 4 – lignite; 5 – water table in natural conditions; 6 – marls; 7 – boreholes; Q – Quaternary; Tr – Tertiary; Cr – Cretaceous*



Groundwater flow model for premining conditions

At the first stage groundwater flow model was performed under natural conditions, i.e. before the dewatering operation. Steady state simulation was performed using MODFLOW (McDonald, Harbaugh 1984). A quasi-three-dimensional two-layer numerical model has been developed, which covers the area of 1550 km^2 with 90 rows and 109 columns. It was assumed there are two layers: the quaternary and tertiary over-lignite porous complex - called layer I, and the porous and interstice complex which includes the cretaceous layer and a the tertiary underlying aquifer within the area of the deposit – called layer II. The limits of the model exceed the area of the predicted range of the cone of depression. The north, east and west boundaries are determined by the rivers and the south boundary is the watershed boundary between the catchments area. The boundaries are represented by type 1. H = const, type 2. Q = 0 and type 3. Q = f(H). The effective infiltration Q = const., varies over the area and depends on the lithology of the land. It differs from 4.6 to 15.3% of average annual precipitation. According to calibration process the leakage into the layer II as well as the distribution of the permeability coefficient were estimated for each layer. The water budget for premining conditions is presented in table 1.

Table 1 *Water budget for premining conditions according to modeling study, [m^3/min]*

Layer	Recharge from precipitation	Discharge to Warta river	Discharge to Prosna river	Discharge to other courses	Leakage from layer I to layer II	Discharge out of the model
I	119.6	11.1	7.9	71.4	29	-
II	0	14.2	12.1	0	0	2.7

Groundwater flow model for mining conditions

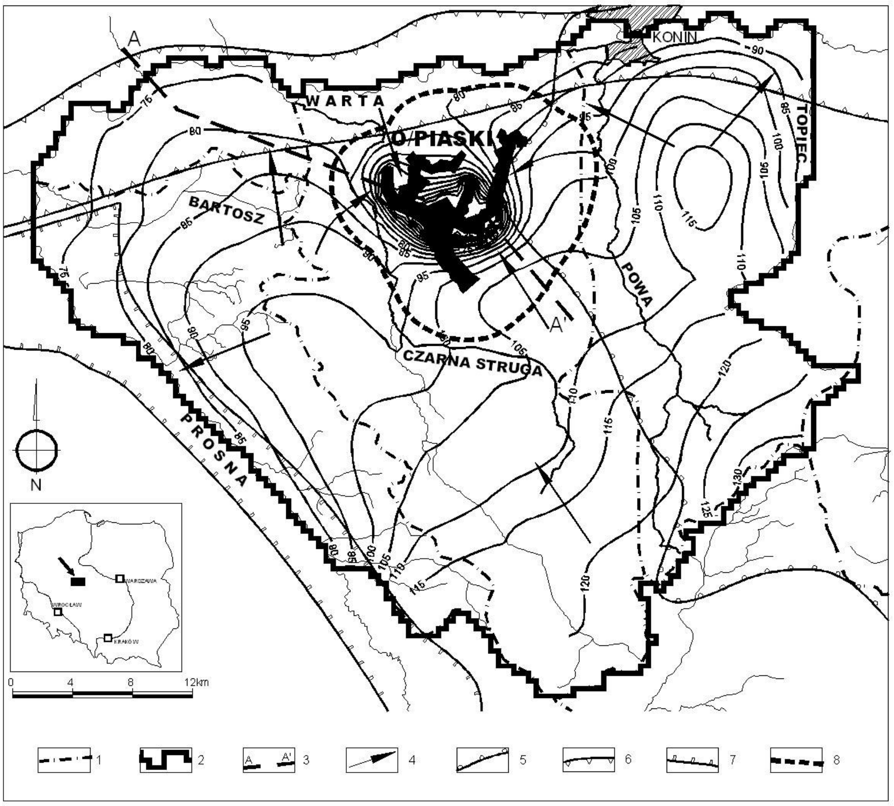
For the groundwater flow model under dewatering condition, the same model has been applied as in the case of premining conditions. The following periods were distinguished during the dewatering operations: 2008–2015, 2016–2025 and 2026–2036. The heads from steady-state runs calculated for premining conditions, were used as initial conditions for the transient simulation. It required activation of specific yield and storativity parameters. It was assumed that the drainage system will be represented by internal boundary conditions type I, where H = f (t) located on the external contour of the open pit, limited by the dewatering wells barriers.

Within the area of the mine drainage the natural proportions of the water balance are changing. According to the previous studies (Dąbrowski 1995, Sawicki 2000) it has been assumed that within the area of the cone of depression, the effective infiltration will rise to 30% of the average precipitation (table 2). Increase of effective infiltration, specific yield and storativity are, except of the dewatering time, the most important factors deciding on the range of the cone of depression. However these factors can't be estimated based on the premining model and reliable data are necessary to estimate these parameters. The configuration of groundwater table in 2025 is presented in figure 2.

Table 2 *Infiltration modulus and effective infiltration coefficient in the lignite mine dewatering areas in Poland (according to Sawicki 2000)*

Mining area	Depth of dewatering [m]	Cone of depression [km^2]	Infiltration modulus [$l/s/km^2$]	Precipitation [mm]	Effective infiltration coefficient [%]
Konin	100	250	4.08	458	29.7
Adamów	45	120	5.69	523	33.6
Bełchatów	250	530	7.44	568	42

Figure 2 *Computer model prediction of the configuration of the water table in 2025 for layer II [m a.s.l.] - "Piaski" open pit. Explanations: 1 – watershed boundaries; 2 – model boundary; 3 – cross section; 4 – main groundwater flow directions; 5 – GZWP no 151 boundary; 6 – GZWP no 150 boundary; 7 – GZWP no 311 boundary; 8 – maximal range of the cone of depression s = 1m*



Results and Discussion

The results of the modelling study for premining conditions indicate infiltration modulus of 1.28 $l/s/km^2$ and it complies with hydrological investigation. The discharge to rivers is 1.95 m^3/s. The recharge of layer I amounts to 7.4% of the precipitation. Layer I, which is almost totally recharge from precipitation is discharged to rivers in 75%, while 25% of the groundwater percolate to layer II, which is discharged by Warta and Prosna river.

The results of the modelling study for mining conditions for 2025 indicate that the groundwater inflow to the drainage system of the „Piaski" open pit will be about 90 m^3/min. Due to the lowering of groundwater table the effective infiltration in the area of cone of depression will rise until 32 % of average precipitation (table 3). The infiltration modulus will increase to app. 5 $l/s/km^2$. The baseflow to the rivers may decrease of app. 16.3 m^3/min.

***Table 3** Water budget for mining conditions (2025) according to modeling study, [m^3/min]*

Lay-er	Recharge from precipitation	Discharge to Warta river	Discharge to Prosna river	Discharge to other courses	Leakage from layer I to layer II	Recharge from static resources	Mine drain-age	Discharge out of the model
I	153.5	9.4	7.9	55.1	118.1	37.3	-	-
II	1.2	13.3	12.1	0	0	1.8	93.0	2.7

The development of the cone of depression will proceed in all directions. The operation of the dewatering system will create a cone of depression whose range will be up to 6 km in layer II. Its range in layer I will be smaller by approximately 1–2 km. To the north of the mine, due to a lack of isolation between the aquifers, the range of the cone of depression will be common for the both layers and it will amount to 4.0 km, including the valley of the river Warta. The changes of effective infiltration in the cone of depression for each stress period is presented in table 4.

On the basis of observations from the region of the mines of Konin Lignite Mine region it can be assumed that the influence of the cone of depression in the household wells will occur principally in the direct vicinity of the mine, i.e. within the distance of 1.5 to 2.0 km. These wells take mainly subsurface water that can be found in thin sandy layers, which do not form a continuous aquifer.

***Table 4** Changes of effective infiltration in the "Piaski" area of cone of depression*

Year of mining operation	Area of the cone of depression [km^2]	Infiltration modulus [l/s/km^2]	Effective infiltration [mm/year]	Precipitation [%]
0	-	1.29	40.6	-
2015	81.8	5.3	166.8	33.4
2025	151.9	5.14	161.8	32.1
2036	227.5	4.96	156.1	31.2

The water from the wells will be discharged to the surface drainage system to the Warta river, through a network of pipelines and ditches and channels constructed along the external boundary of the open pit. According to polish rules the water drained within the catchment area of the given river has to be directed to its riverbed below the mine. In order to control the groundwater level and the impact of drainage on the natural environment, an internal and external monitoring system will be installed.

Once the dewatering operation has finished water reclamation of the post-exploitation reservoirs is foreseen.

Conclusions

The groundwater flow model for mining conditions base on data obtained from the calibration of the premining model developed for natural conditions. Mostly, due to lack of reliable data a steady-state simulation is performed for premining conditions. But the mininig conditions require transient simulation. In this case, the most important factors deciding on the range of the cone of depression are, except the time of dewatering, increase of effective infiltration, specific yield and storativity. These data can't be estimated based on the premining model. In this case reliable data are necessary, based on the similar conditions, which enable to estimate open pit dewatering impact on water environment with higher accuracy.

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