MODELLING OF THE BELCHATÓW OPEN-PIT IMPACT ON THE GROUNDWATER ENVIRONMENT

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ABSTRACT

The Belchatów lignite open pit has an area of 23 km^2, depth of 200 m and is being drained for 24 years. The USGS MODFLOW program was used to reconstruct past and to present the existing hydrogeological conditions in the aquifers within the Belchatów open pit influence area. The model simulation was performed for steady state conditions for the period before drainage system has been put into operation and also for transient conditions as a result of mine dewatering. The results obtained during simulation present the impact of mine dewatering on groundwater circulation and groundwater balance in the surrounding area of 526 km^2.

INTRODUCTION

The lignite open cast mine Belchatów is the second open pit all over the world and has production capacity 38 mill T/y, overburden stripping is 110 mil m^3 yearly, the depth of operation is about 200 m and the area of the open pit is 23 km^2. At present the exploitation is conducted on the Belchatów Field, whose area will amount to about 33.6 km^2 and the maximum depth of operation will attain 280 meters. In 2002 overburden stripping and in 2007 lignite production will start at the adjacent Szczerców Field. The designed area of Szczerców open-pit will be about 21 km^2, while the depth of the open-pit will reach maximum 290 meters. The dewatering system in Belchatów open-pit has been operating since 1975. The total volume of water pumped-out from the beginning to the end of 1998 is up to 4 billion m^3. The average lowering of natural groundwater table within area of mining operation is about 200 m. The dewatering operations result in lowering of groundwater table not only in the open pit area, but also in its surroundings. It effects cone of depression which varied from 106 km^2 in 1976 to 635 km^2 in 1993, presently is about 460 km^2. It will be increased after starting of dewatering system on the Szczerców field in 2000. Hydrological and hydrogeological studies indicate influence of dewatering on all elements of hydrogeological system on areas being under its influence. In 2038, it is planned to complete lignite production at the Belchatów mine. A general purpose of the management of abandoned pits will be to create there two huge water reservoirs, which area will reach 32.5 km^2 and volume of 3.4 billion m^3. The return to the natural condition will be impossible due to irreversible changes that will occur in the area of the closed mine.

The USGS Geological Survey's program MODFLOW has been used to simulate the premining conditions, as well as the conditions changed by the operation of the dewatering system and its impact on the environment. Use of model to reconstruct known groundwater head distribution and flow rates identifies which elements of the hydrogeological system are the most influenced by the mine drainage system. The huge availability of data from before and during mining allow identifying all these elements with greater validity.

HYDROGEOLOGICAL CONDITIONS

The Belchatów Lignite Basin is deposited in the tectonic rift valley having length of 60 km and width of 0.5 - 2 km. Its maximum depth amounts to 500 m. In the central part of the rift valley the Debina salt dome divides the lignite basin into the Belchatow Field and Szczerców Field.

The Mesozoic base is formed by Jurassic and Cretaceous rocks. Mesosoic aquifers are: fractured limestone, marls and sandstone. This aquifer occurs at the depth about 40 to 100 m around rift valley, but within the rift valley at the depth of about 400 m. The average hydraulic conductivity for this fissured aquifer is about 5 m/day, but is very diversified; the highest permeability occurs in karstified limestones.

The Tertiary formations occur within the rift valley at the depth 90 to 400 m and can be divided into three principal series with regard to the hydrogeology (Kuszneruk and Seweryn,1987):

- under lignite series, mostly sandy ones,
- lignite series,
- overburden with considerable amount of sand.

Permeable sand strata have the hydraulic conductivity of about 1 to 3 m/day and are about half of all Tertiary formations. The other half are clays and lignite - both impermeable.

Quaternary formations occur in the whole area. Their maximum depth amounts to 300 m occur in the northern part of Belchatów Field in post glacial burried valley. In the other parts of the region the depth of Quaternary formation is about 90 m. It consists of sand-gravel about 70 percent and 30 percent of clays. The average hydraulic conductivity for sand-gravel series is about 20 m/day. The aquifers occurring in the particular stratigraphic series have many geological and hydraulic connections, so the whole complex of the permeable rocks create one huge and heterogeneous aquifer in the whole region.

The lignite basin and its surroundings are in the south part of Widawka River basin with area of 1525 km^2. The natural groundwater table occurred 2 to 5 m below the terrain surface with flow towards N-W direction. The water balance for the Widawka river basin before dewatering of the mine resulted in that for total sum of recipitation feeding this region - 620 mm/y, total runoff has taken 29 percent, but 71 percent has been evaporated. The baseflow was 3.53 l/s/km^2 (Sawicki, 1977).

MINE DEWATERING SYSTEM

The dewatering system has been operated at Belchatów open-cast mine since 1975. Groundwater has been lowered by large-diameter pumping wells system. The wells are placed in the barriers protecting open-pit, draining its forefield and taking static water within the pit. The depth of pumping wells depending on their location and tasks varies from 100 to 350 m. The total number of wells drilled so far is about 1500, and 320 ones are operated at present. The mine inflow ranged from 180 m^3/min at the beginning and had its maximum 450 m^3/min at 1985, presently is 330 m^3/min. In 2000 the dewatering opera-

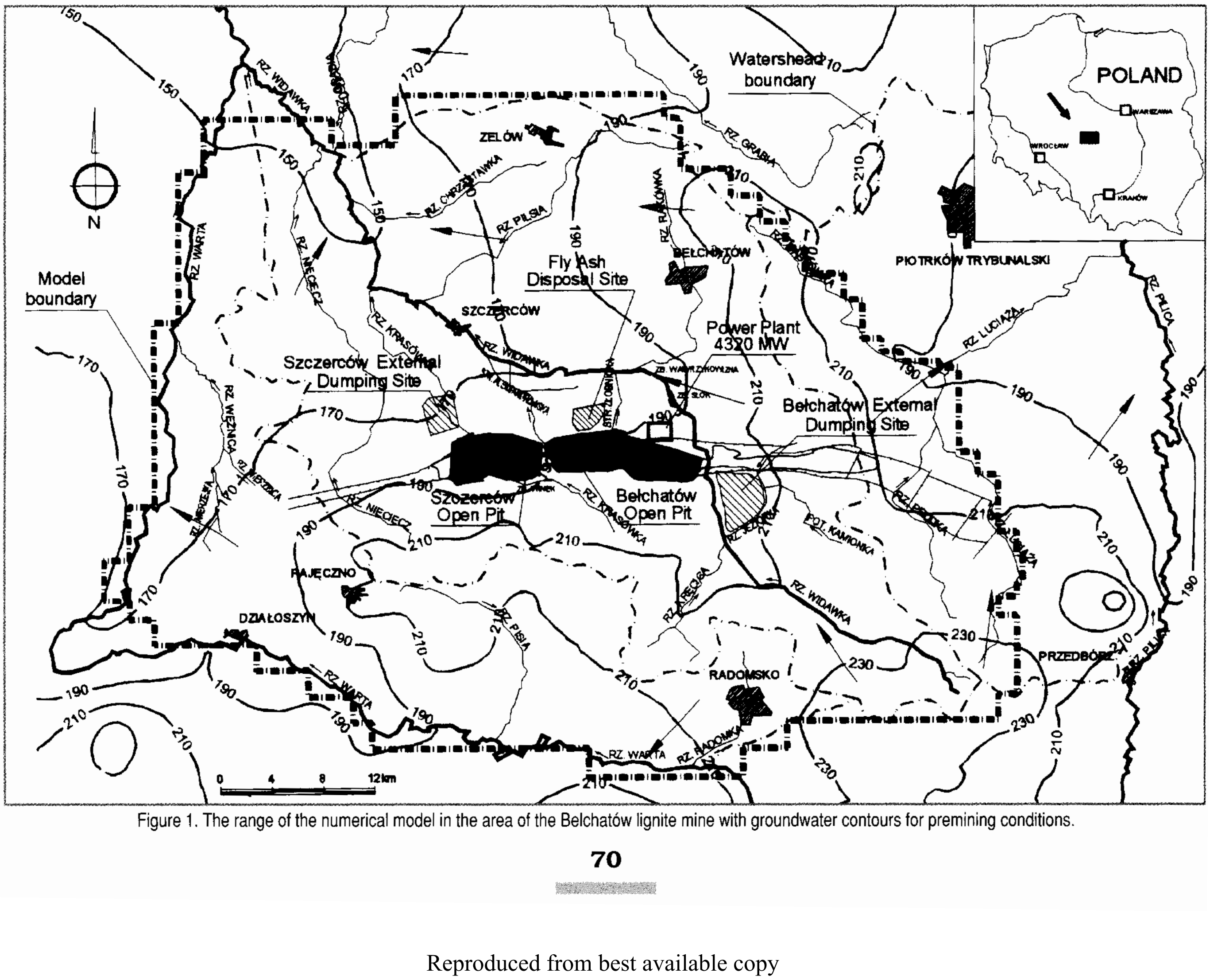

Figure 1. The range of the numerical model in the area of the Belchatów lignite mine with groundwater contours for premining conditions.

tions will start at Szczerców Field 8 km from the Belchatów open pit operated dewatering system. It is expected that the mine inflow in the first 3 years will reach in Szczerców 330 m^3/min.

To monitor and to control the lowering of groundwater table and reduction of pressure in the confined aquifers the system of internal and external piezometers has been developed. At present the total number of external piezometers is about 380 and the internal piezometers is about 420. Most of them were taken into consideration as a target points in modelling study.

CONCEPTUAL MODEL AND COMPUTER CODE SELECTION

To determine the dimensions of the numerical model and the design of the grid the conceptual model was built. The lateral boundaries were beyond the radius of influence of the measured and predicted cone of depression. It was based on physical boundaries - rivers and hydraulic boundaries that include groundwater divides and streamlines (Figure 1).

The study area is vertically divided into two hydrostratigraphic units:

- the first one consists of a porous Quaternary aquifer [Q], Tertiary aquifer outside the lignite seam and Tertiary lignite overlying aquifer [Tn] on the area of the rift valley, where the lignite seam appeared - named as layer I;
- the second consists of a Mesozoic fissured-karstic aquifer [M] together with Tertiary lignite underlying aquifer [Tp] on the area of the rift valley - named as layer II.

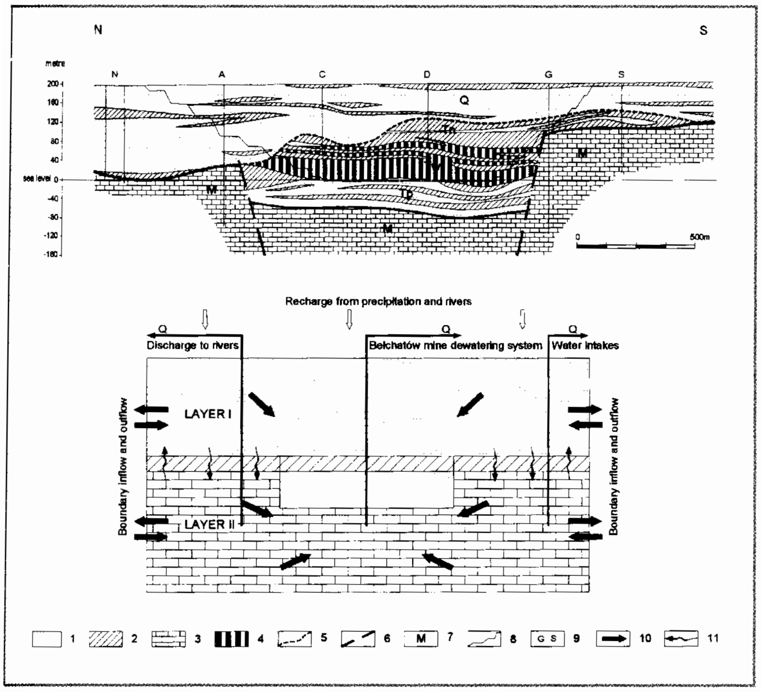

Figure 2. Simplified geological cross-section N-S (Bieniewski et al.,1980) with the conceptual model suitable for numerical modelling.
Explanation: 1-porous, permeable formations, 2-impermeable and slightly permeable formations, 3-fissured-karstic formations, 4-lignite, 5-boundary of the Quaternary aquifer, 6- faults, 7-symbols of aquifers, 8- open-pit limits, 9- dewatering wells barriers, 10 - direction of groundwater flow, 11- direction of groundwater percolation.

Both layers are separated by a lignite seam [Tw] with clay complex considered as impermeable. Outside the rift valley the layers are divided with the top of Mesozoic complex (Figure 2). Recharge to the top layer occurs by percolation of precipitation. Discharge occurs as baseflow to the rivers and streams as well as by downward leakage to deeper aquifer. Relatively impermeable lignite seams with clay beneath impeded the vertical flow of water. Outside of the lignite deposit the layers contact directly in many places at erosion furrows or through hydrogeological windows. The layer II is recharged by leakage from top layer and discharged by two main rivers of the area - Warta River and Widawka River. Some recharge and discharge of this layer occurred as underflow across east boundary.

From the both layers pumping of groundwater for municipal and industrial intakes was conducted. Presently, the main role in groundwater drainage has Belchatów mine dewatering system. A part of streams which are in cone of depression are changing their character and recharge the aquifers. In the most part of the area the potentiometric pressures in both layers are similar or the same.

GROUNDWATER FLOW MODEL CONSTRUCTION

The numerical model used for simulation of the groundwater flow system was USGS modular three-dimensional finite-difference ground-water flow model MODFLOW (McDonald and Harbaugh, 1988).

Horizontal flow within the confining bed was considered negligible, thereby allowing usage of the quasi three-dimensional option. The model simulated horizontal flow within each layer and vertical flow between layers through the confining bed. The upper layer was simulated as the unconfined aquifer and the lower layer as a confined/unconfined aquifer with variable transmissivity. An equivalent porous medium is assumed for the fractured-karstic layer II, a reasonable assumption in view of the regional scale of the problem (Mullens, 1964).

The study area of about 2500 km^2 was represented by a grid consisting of 86 rows and 151 columns and 2 layers, or 25972 nodes of which 24222 are active. The grid was irregularly spaced with a finer mesh near the mine workings. Node spacing ranged from 100 m near the mines to 1000 m near the model boundaries.

The vertical expansion of layers varies in space corresponding to information obtained from mineral exploration records, water well logs and geological maps of the region. The top of the layer I equalled to the water-table level in premining conditions, while the bottom was determined with the ordinate of the top of Mesozoic formations, but in the area of the lignite seam it corresponded to the ordinate of upper lignite deposits. The top of the layer II corresponded to the bottom of layer I, while in the area of the deposit it was equal to the ordinates of lower lignite deposits. Due to the lack of information about the active zone of this layer it was assumed that its thickness is 200 m on the whole area.

Boundary conditions and filtration parameters

The grid nodes were used for determination of external and internal boundary conditions. Along the south and west limits of the model where its boundary corresponds to the Warta River the specified head boundary was assigned. In the east limits which are represented by Luciaza and Dabrówka streams head dependent flux boundary was set in layer I, but for layer II specified head boundary was assigned equal to hydraulic head in layer II along this limit. All other lateral boundaries are regional divides and were simulated as a no-flow condition.

The internal boundary conditions are represented in the model by the Widawka river and their tributaries, as well as tributaries of the Warta River. They were included in layer I as river nodes, which represent head-dependent flux boundary. It assumes change of flow between the river and aquifer, depending on the hydraulic gradient between them. In the layer II only the Widawka River was simulated. The value of streambed conductance from 8E+2 - 2E+3 m^2/d resulted from trial and error adjustment during calibration and provided the best match between measured and simulated gains and losses and hydraulic heads along the rivers.

Groundwater intakes operated in the premining period were not simulated in the model representing steady state conditions because there was only very few information and very small scale of this element to be taken into consideration in water balance for years 1954 –1975 (Sawicki, 1977).

The upper boundary of the model was a recharge boundary, added to the fluctuating water table. It was represented by constant-flux boundaries. The evaluation of recharge of the modelled area was based on field measurements of baseflow to streams and rivers and the water balance for Widawka River basin before dewatering of the mine (Sawicki, 1977). For the steady-state simulation three zones of uniform recharge was selected: 1. zone of recharge of 0.0005 m/d (29.5 percent of the average annual precipitation) covers the upland areas - well permeable, built of fluvioglacial and hill sands, 2. zone of recharge of 0.0002 - 0.0003 m/d (11.8 - 17.7 percent of the average annual precipitation) covers upland areas, slightly permeable, built of various types of clay, 3. zone of recharge of 0.00027 m/d (15.9 percent of the average annual precipitation) covers valley areas, with shallow located water table, which due to intense evapotranspiration loose large amounts of water.

The water percolation between layers was simulated by confining-bed leakage (vertical conductivity of the confining bed divided by its thickness) and was determined from geologic data and models prepared in 80-ties (Fiszer et al.,1988; Przybylek et al.,1989). Three types of hydraulic contacts were selected: 1. direct hydraulic contact with leakage of 1 d^{-1} - when both layers contact directly through erosion furrows and hydrogeological windows 2. indirect hydraulic contact with leakage of 0.00005 - 0.002 d^{-1} - when layers are separated one from another with slightly permeable formations 3. no hydraulic contact with leakage of 0 d^{-1} in the area of the thick lignite deposits with clay beneath it.

Hydraulic properties were determined by hydraulic conductivity, specific yield and storage coefficient. All the input parameters were derived from a combination of field measurements, previous models and calibration of the new created numerical model. Both in the case of layer I and layer II the parameters were assumed as a medium one in the assumed thickness of layers. The value of hydraulic conductivity for both layers varies from 0.25 to 50 m/day. The highest transmissivity is in the northern part of Belchatów mine, where Quaternary burried valley occurs. Specific yield for layer I varied depending on lithology from 0.07 to 0.15, while for layer II was assigned as regional parameter equal to 0.03. Storage coefficient for this layer was determined in the range of 0.02 - 0.002.

PREMINING CONDITIONS

To reconstruct ground-water head distribution and flow rates, in the premining conditions steady-state simulation was performed. The historic data were available from the geological and hydrogeological reports performed in the years of 1954 - 1975 before dewatering began. The model was calibrated by varying hydraulic conductivity, recharge by precipitation and leakance until simulated heads and flows agree as nearly as possible with field data. The basic elements which decided on the correctness of the model were: 1. match between modelled and measured heads 2. correctness of the modelled underground runoff with the actual value calculated for premining conditions. As a result of the model calculations the premining groundwater flow system was recreated and the following groundwater balance was obtained:

Layer	Recharge from precipitation	Flow across the boundary of the mode	Discharge to streams and rivers	Discharge as downward leakage
I	616.8	-2.5	497.7	116.6
II	0	14.6	131.2	0

Table 1. Groundwater balance for premining conditions [m^3/min].

These values corresponded to those calculated with use of hydrological methods. The simulated baseflow for Widawka basin was 3.75 l/s/km^2 vc. 3.53 l/s/km^2 calculated for this area from stream fluxes. For the whole area of the model underground runoff amounted to 4.17 l/s/km^2. The layer I, which received all its recharge from precipitation, discharged 19 percent by downward leakage and 81 percent as discharge to streams and rivers. The layer II received its recharge from the layer I by downward leakage (89 percent) and across the eastern boundary from the underflow (11 percent). The modelled heads for steady-state condition provide a match to premining field map (Table 5). The regional flow pattern and gradients in both layers were similar and indicated that from the regional point of view there were no significant difference in potentiometric surface between two modelled layers.

MINING CONDITIONS

On starting the dewatering operation the system of monitoring the river flow, the mine-water inflow and the development of the cone of depression was started. It provided the huge amount of data prepared and reported by mine survey and Institute of Meteorology and Water Management (IMGW) (Wachowiak et al., 1975-1998). For simulation of groundwater flow system in mining conditions the identical limits of the model and the external boundary conditions as for preminig model were used. The following four periods were distinguished during the dewatering operations: 1975-1980, 1980-1985, 1985-1990 and 1990-1996. The heads from steady-state runs were used as initial conditions for the transient simulation. The calculated heads from the end of each stage were used as input to the next stage. In every stress period the calibration of the model parameters was performed. The numerical model developed for simulating preminig conditions was adapted for mining conditions by making additional modifications. They were made to the premining input data to reflect the changes caused by mine development.

Boundary conditions and filtration parameters in the area of the cone of depression

Open-pit dewatering system was simulated with time-variant specified-head nodes situated in layer I to simulate pumping wells of internal overburden barriers and in layer II to simulate pumping wells of external and main internal barriers - outline of open-pit dewatering zones. The time-variant specified-head boundary linearly interpolates boundary head for each boundary cell. Its starting and ending value of head correspond to head values in dewatering barriers in the beginning and end of each stress period (Leake and Prudic, 1994).

On the area of the cone of depression the interaction between rivers and aquifers is changed as follows: 1. the river beds are artificially sealed, therefore infiltration of surface water into the aquifer is impossible; 2. the river beds loose completely water, which was taken over by the mine dewatering system; 3. rivers reduce their flows due to direct infiltration of river waters from the beds to the mine drainage system and also by decreasing the baseflow. In case of nodes simulating the sections of sealed rivers, as well as streams which dried due to the influence of the mine, the head dependent flux boundary was removed.

On the regional depression cone area the elements of natural water balance change. Surface run-off disappears, evaporation and baseflow to rivers decreases, while the effective infiltration to aquifers increases. Model simulations indicated that rate of recharge from precipitation was higher than before mining. In the area, where the water table was lowered by more than 3 meters additional three classes of recharge were assigned. It was characterised by increased value of effective infiltration in the area of the cone of depression, with values respectively 48.3 percent for sandy uplands and river valley areas and 28.9 percent for clay uplands.

Due to the dewatering of the mine some old municipal wells dried. Water is now supplied from new deeper water wells. Pumping from the biggest commercial, municipal and industrial wells was incorporated into the model.

Ash disposal from neighbouring Belchatów Power Plant is located from 1983 on Bagno-Lubien site. The disposal is located on the Northern side of Belchatów Open Pit at a distance of about 200 m north from dewatering wells. At present the area of disposal site is within the impact of mine dewatering operations which resulted in that the natural direction of groundwater flow has been changed from north direction to the south i.e. toward the dewatering system. The disposal is underlain by sand and gravel and has no liner, so the surface waters were contacted here with shallow Quaternary aquifer and also, with lower aquifer. The infiltration of water from disposal site is simulated by constant flux boundary, whose value was changed in each simulation period according to actual infiltration - average 25 m^3/min.

The internal overburden dumping was started in 1989. Mining operations have destroyed the premining top aquifer and dumping has replaced the host rock by spoil material. Overburden is placed over areas represented by nodes where the layer I and impermeable lignite seam had previously been simulated. In stage of simulation 1990 - 1996 the internal dumping space was simulated by constant hydraulic conductivity of 1.5 m/d and specific yield 0.07. The leakage parameter was changed to 1 d-1 simulating direct hydraulic contact between layers.

Model calibration and evaluation of its quantity

The goal of model calibration in transient simulation was to find a set of parameters that would allow the model to reproduce hydraulic head and fluxes to the mine dewatering system during four different periods. The following calibration values were taken into consideration: 1. match between modelled and measured mine water-inflow at the end of each period in [m^3/min] (AA), 2. match between modelled and measured mine-water inflow for a selected period in [m^3/min] (BB), 3. match between modelled and measured total mine water inflow (CC) in [billion m^3] 4. match between computed and measured heads expressed by the average difference between simulated and measured head and represented by the mean error (ME), the mean absolute error (MAE), the residual standard deviation (RSD). For a good calibration, the residual standard deviation should vary much less than the total change in head across the model (RSD/H), perhaps 10 to 15 percent (Rumbaugh, 1995) (Table 2, 3).

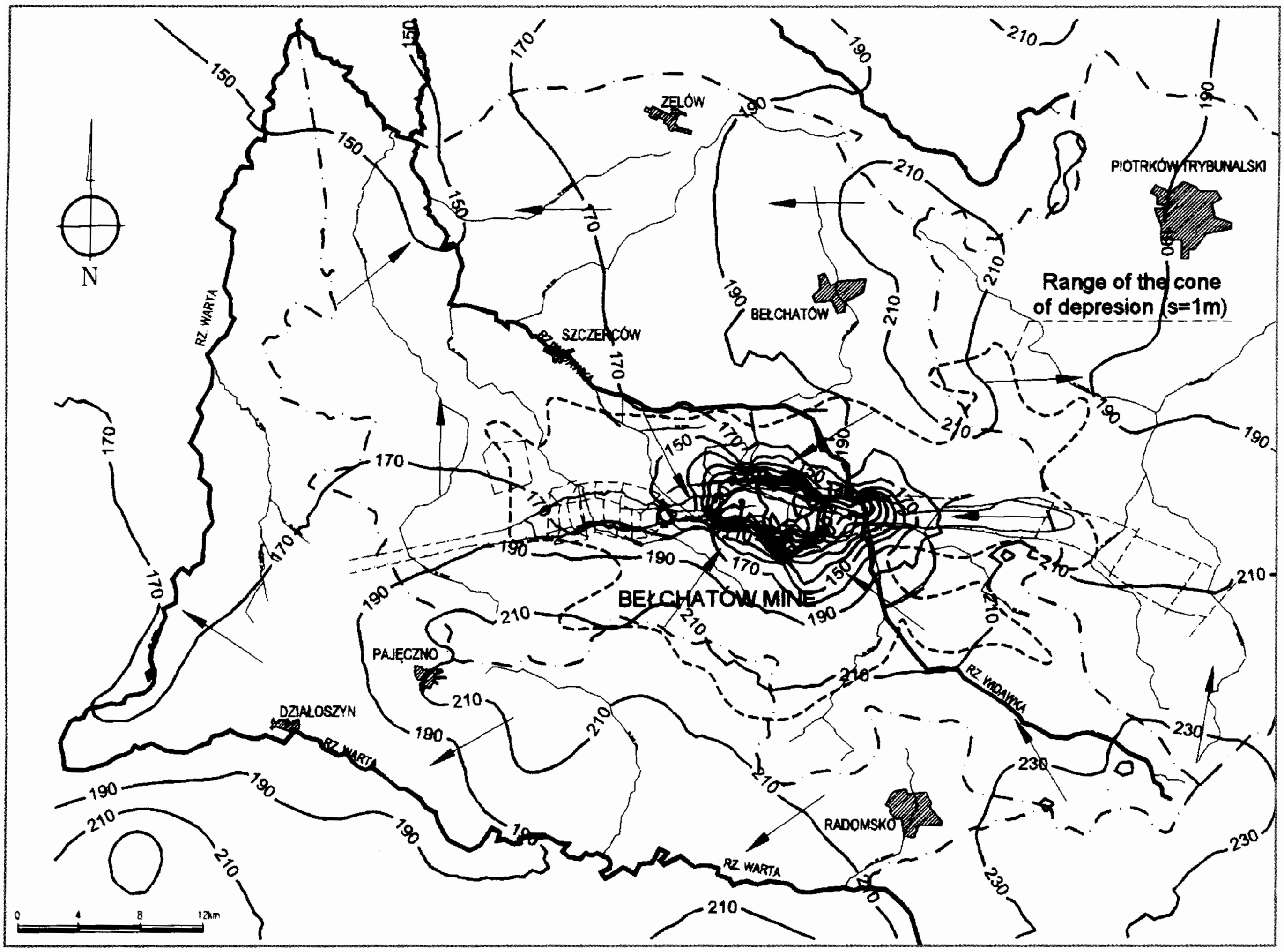

Figure 3. Groundwater table after 21 years of dewatering.

	1975 - 1980		1981 – 1985		1986 - 1990		1991 - 1996	
	X	Y	X	Y	X	Y	X	Y
AA	305	329	405	367	367	320	348	348
BB	261	264.4	381	361.4	317	317	320	344
CC	716	724	1,716	1,644.6	2,549.1	2,477.7	3.486.9	3,562.8

Table 2. Match between modelled (X) and measured (Y) by IMGW mine water inflow.

	Premining condition			1985			1996		
	Layer I	Layer II	Entire	Layer I	Layer II	Entire	Layer I	Layer II	Entire
Target	558	336	—	421	312	—	448	388	—
ME	0.57	-0.31	0.21	2.19	2.94	2.51	1.72	1.91	1.81
RSD	4.28	4.22	4.28	11.1	12.6	11.8	9.48	14.96	12.3
MAE	2.87	2.93	2.9	6.39	7.6	6.9	5.64	9.26	7.32
RSD/H	0.044	0.037	0.036	0.039	0.046	0.039	0.039	0.053	0.044

Table 3. Match between modelled and measured heads.

Groundwater balance in the range of the dewatering influence

The groundwater balance obtained at the end of simulation has shown that due to mine dewatering 348 m^3/min (Q8) the total sum of recharge from precipitation (Q1) has increased from 616.8 to 698.7 m^3/min. Additional recharge 26 m^3/min (Q5) occurred from the disposal site located in the north part of Belchatów open pit. Influence of the cone of depression on the river runoff brings about decrease of discharge to streams (Q6) from 628.9 m^3/min to 483.2 m^3/min. Discharge as downward leakage from layer I to layer II (Q7) increased from 116.6 to 405.0 m^3/min. Mine dewatering caused also discharge from groundwater storage (Q3). The new elements of drainage are water intakes (Q4). Flow across the boundary of the model remained almost the same in each simulation (Q2). The baseflow for model area increased from 4.17 l/s/km^2 to 4.89 l/s/km^2.

The calculated inflow balance to mine drainage system in 1996 allowed the sources of inflows and their relations with useful balance elements of the modelled area to be determined. The balance of inflows to the drainage system of the pit can be presented by the formula (Table 5).

The presented calculations indicate that the predominant element of the balance of mine inflow (Qc) is the dynamic element which consists of dynamic inflow (Qd), additional dynamic inflow as a result of decrease of loss for evaporation by lowering of the groundwater table within the cone of depression (Qev), water infiltration directly from water courses (Qi) and artificial groundwater resources (Qa) as a result of water infiltration from waste disposal site. The mine inflow from static resources (Qs) amounted to 25.8 percent vc. 10 – 48 percent for year 1990 – 1995 calculated from hydrological investigation (Sawicki, 1999).

POSTMINING

In 2020 it is planned to complete lignite production at the Belchatów open-pit. The depth of the final excavation will reach 280 meters, the area about 17.5 km^2 and its total volume more than 1.9 billion m^3. Adjacent Szczerców open pit, which will finish lignite exploitation in the in 2038 will reach the depth of about 290 meters, area of about 15 km^2 and volume more than 1.8 billion m^3. A general aim of the management of both abandoned pits will be to create there huge water reservoirs (Kozlowski et al., 1999).

The final reclamation of the Belchatów open pit related to its partial backfilling by the overburden from Szczerców open-pit will start in 2021. The end of this work is planned in 2036, when the Belchatów final excavation will reach depth of about 110 meters. Although the dewatering system working in the Szczerców open-pit will result in the lowering of groundwater table in the area of the Belchatów final excavation. However, the modelling studies indicate that groundwater table reconstruction in this area will exceed the rate of overburden storing in the final excavation, so it will still be necessary to maintain the dewatering system around it. It will allow safe storage of overburden. The works related to shallowing the Szczerców final excavation by the overburden from Szczerców external dumping site will be started in 2036 and completed in 2050. The final depth of reservoir will attain about 100 meters. To allow safe storage of overburden, it will be required to maintain dewatering system around it. Furthermore, in order to avoid earlier filling of the Belchatów reservoirs with water and make impossible to increase the hydraulic gradient over the salt diapir the dewatering system of the Belchatów open-pit will still have to operate. The main goal of this is elimination of water flow through the stock zone and prevention of the washing out of the salt diapir and protection of the water against pollution with saline water from the stock area. The preparation of both excavations for filling with water will require additional works to obtain the sufficient stability of slopes. It will be completed in 2055. Since 2056 the process of filling the post-mining excavations with water will start. The cumulative volume of the reservoirs will reach 3.4 billion m^3 and the area more than 32.5 km^2.

As the slopes of Belchatów Open pit final excavation are being shaped just now and also, for reason of protection of a salt diapir as well as for improvement of lignite mine management at adjacent Szczerców open pit, the problems of final reclamation in both reservoirs require thorough analyses to be made as early as now.

Layer	Q1	Q2	Q 3	Q4	Q5	Q6	Q7	Q8
I	671.4	-2.5	89.7	1.3	26	384.2	405.0	——
II	27.3	15.5	0.2	12.4	0	99.0	0	348

Table 4. Groundwater balance at the end of simulation [m^3/min].

	Qc	Qs	Qd	Qev	Qi	Qa
m^3/min	348	89.9	141.9	81.9	8.3	26
percent	100	25.8	40.8	23.5	2.4	7.5

Table 5. The balance of inflows to the drainage system of the pit.

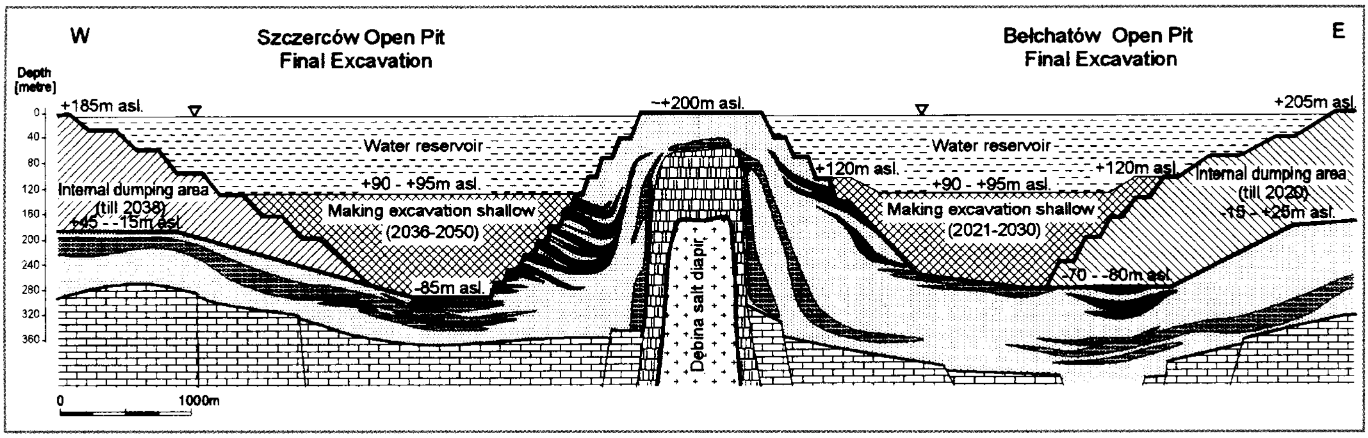

Figure 4. Final excavation at Belchatów/Szczerców Open-Pits.

The postmining excavations of the Belchatów and Szczerców open-pits will become a new element in the regional groundwater circulation system. In the whole area a new hydrogeological system will be formed, with reservoirs filling with water being a part of it. In the numerical model the internal boundary conditions simulating the open-pit dewatering system will be removed. In order to image the postmining reservoirs, in nodes simulating them new value of hydraulic permeability and specific yield will have to be assigned. Furthermore, assuming that in the Belchatów area the precipitation is equalised by potential evapotranspiration, lack of recharge from precipitation should be assigned in the reservoirs area. As shown in modelling study in the cone of depression the amount of effective infiltration from precipitation increases with the lowering of groundwater table. At the stage of water table reconstruction it will return again to its natural values. The dried water courses will be recreated.

The calculation made until now for natural time of filling the reservoirs with water has shown that this process will last for about 70 years. So there is a need to carry out modelling studies and investigations for determination of possibility to make this process shorter, for example through the supply of additional water amount from outside the cone of depression, which is connected with the preservation of disposable water. It would allow to: 1. speed up liquidation of the depression cone effects, 2. reduce time of water protection against being saltlogged from salt diapir, 3. improve the stability of the open pit slopes by ensuring an advance of the increment of water table in the reservoirs relative to the natural increments of groundwater table in the rock mass, 4 cut down detrimental process of slopes abrasion while reservoirs filling

The project for management of Belchatow Mine final excavations is first to such an extent, not only in Polish lignite mining as regards his depth and volume. Solution can be performed with use of the existing, calibrated numerical model. It will be a great importance not only for this mine but also for other big surface mines.

It will allow to obtain the information related to: 1. optimum depth of water ponds, 2. the dynamics and duration of the reservoirs water filling and groundwater table reconstruction in natural conditions and with enhancement of recharge of waters from outside the cone of depression, 3. changes of hydrogeodynamical and hydrological conditions in the region of mine during the course and on completion of water filling, particularly groundwater flow circulation and groundwater balance, 4. stability of slopes and edges of ponds during filling with water (waves effect).

SUMMARY

The dewatering operations in Belchatów open pit resulted in lowering of groundwater table in the area of about 460 km^2, at present. The area will increase to about 800 km^2 after starting Szczerców Open-pit dewatering system. The results obtained during the computer simulation indicated that the lowering of groundwater table brings about changes of runoff regime and character of groundwater flow circulation. Influence of the cone of depression of the river runoff brings about decrease of river flow even their periodical disappearance. Water percolating down from the river beds is one element of drainage system inflow. The leakage between layers decreased more than three times. On the other hand induced groundwater resources were activated. As a result of decrease of loss for evaporation by lowering the groundwater table occurred additional dynamic inflow. The decrease in evapotranspiration and surface runoff in the area of the cone of depression resulted in increase in effective infiltration. Another element of dynamic inflow was an artificial groundwater resources by infiltration of water from a neighbouring power plant disposal site.

The above calculations indicated that the forecasts related to the influence of dewatering on adjacent areas should be conducted with care and take into consideration the possibility of large increase in renewable resources related to the reduction in evapotranspiration and surface run-off and with increase of the effective infiltration and direct infiltration of water from

rivers to the aquifers. These processes resulted in significant reduction of the actual range of the cone of depression, and thus, in a reduction of the negative influence of dewatering on the water environment.

The numerical model, which presently successfully operates for the determination of the influence of the existing dewatering system onto the water environment should be used in forecasting the changes in water environment, which will take place during reclamation of groundwater table after the operation of dewatering system is ceased. The calculated groundwater inflow rates to the liquidated post-mining operations will enable as early as now to design an optimum dewatering system of open pits to be reclamaited in the future. The findings will allow to use options which will make possible to take correct actions aiming at the minimisation of harmful environmental impact of the undertaken project and also, to estimate costs relevant to the stage of controlled water filling of such a type of excavations.

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