The use of computer modelling systems and data analysis monitoring threats in connection with forcing salty mine waters into a rockmass

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Abstract: In connection with work the object of which is to limit the volume of salt mining waters supplying surface water- courses, PRGW prepared a project concerning the salt water injection into Sandstone of the Uppersilesian Sandstone Series in the "Jaworzno" coal mine area. Simultaneously with drilling works a computer simulation of the phenomena which could accompany the process of water pumping was introduced.

Information concerning geological structure, geotechnical, hydrogeological and other parameters was introduced into the data base. Then, digital models of geological structure of the "Jaworzno" coal mine area were prepared. A three-dimensional model of underground workings in the pumping area was also made.

As the next stage a computer simulation of hydrogeological phenomena that may accompany the process of water pumping was prepared. For the monitoring of water pumping purposes, the Voxel Analist program was used. This program enables to work in the three-dimensional space. The computer simulation allowed to prepare hydrochemical models for the particular periods and to observe changes of chemical composition of waters in the investigated area.

1 INTRODUCTION

One of the elements of harmful mining influence on the environment is salt mining waters discharge to surface streams. The problem concerns the eastern part of the Upper Silesian Coal Basin where the largest salt water inflows to mining workings are observed (Figure 1). Just like other mines in the region, the "Jaworzno" coal mine, is forced to dispose salt waters to The Vistula Riverance its tributaries. This results in serious disturbances in ecosystem and reduces the usability of river waters for municipal and industrial purposes.

The "Jaworzno" coal mine has commissioned Przedsiębiorstwo Robót Geologiczno-Wiertniczych [Geological & Drilling Enterprise] and the EUROMINEX company to solve the problem.

A concept was adopted to force salt waters into absorptive strata of the Upper Silesian Sandstone Series, which is below exploitation levels, isolated from them with a thick packet of impermeable rocks. After a series of tests and analyses that had been conducted by both Polish and foreign specialist since 1992, a pilot injection installation was launched (Kuś 1992). Three injection bore-holes were made, two boreholes (CH-2 and CH-3) drilled from underground workings and one surface bore-hole (CH-1).

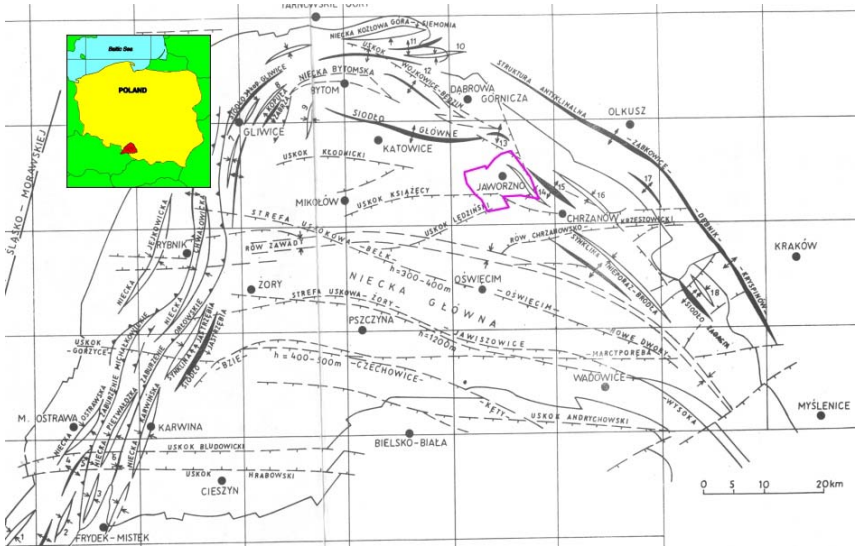

Figure 1 A map of the Upper Silesian Coal Basin main structures with the "Jaworzno" coal mine mining area

Parallel with the injection installation, work aimed at creating an efficient and easy-to-operate system to monitor the injection impact on the natural environment was carried out. In conformity with the assumption made previously, the system was based on data pertaining to the geological structure and hydro-geological conditions of the area collected in a digital form. The data stored in a geological data base and was used for making structural models of the rock mass, simulating phenomena that may accompany the pumping process and, in consequence, was used in the system of monitoring the pumping impact to the environment (Kuś 1999).

Software of the following companies was used for the project implementation: Intergraph (MGE, ERMA, Irasb, Voxel Analist), Bentley (MicroStation), Microsoft (SQL Server). The whole work was carried out with the use of the TD410 graphic station supplied by Intergraph.

2 CLASSIFICATION AND CHARACTERISTICS OF THE OLLECTED INFORMATION

The collected information pertained to:
- the area geological structure
- hydrogeological conditions
- hydrochemical conditions

On the ground of general observation of changes in lithology of the coal mine area, a generalisation scheme for geological structure in the vertical profile was

adopted. Strata of thickness not exceeding 10 m were combined into complexes and designated in the same way as the strata of the largest share in the particular complex. The subsequent generalisation pertained to water permeability. Sandstones and conglomerates were classified as permeable and the remaining rocks as impermeable.

The next step was the establishment of location of individual series ceilings and floors. In order to separate a series, a percentage share of rocks of particular permeability was adopted as the superior criterion. The stratigraphic criterion was used as the secondary one. In the MicroStation programme, fault identification points were collected, basing on maps of seams and bore-hole cards. The faults selected for introduction were identified during mining work and localised in bore-holes, of thrust volume exceeding 50 m. The identification points were then scanned and introduced to the data base by means of the MGE Modeller software.

The following information was selected out of the bore-hole documentation and the geological documentation: information pertaining to the filtration coefficient, permeability, porosity, hydrostatic levels, as well as geotechnical parameters obtained as a result of geophysical research.

The information collected periodically by a coal mine hydrogeologist was treated as a separate data group. It concerns the volume of water inflow to workings as well as its chemical composition.

3 GENERATING A GEOLOGICAL AND MINING RELATION DATA BASE BASING ON DATA MANAGER TEMPLATES OF THE ERMA PACKAGE

During the preparation work, a great deal of information was collected that needed systematisation as well as introducing interrelations between them. It was done by means of a relation data base co-operating with the MGE environment. The MGE package includes a number of tools allowing for the generation of the data base scheme. It can be done by using the existing scheme or by generating an entirely new one (Figure 2). In this case a scheme was selected by means of an appropriate creator and then modified so that it allowed for the real scale work, in the local co-ordinate system and in the metric unit system. Necessary tables were added and some of them were modified . After adding appropriate glossaries, a data base structure optimal for the project was obtained. Previously prepared data were introduced to the so construed data base (Chryst, Rupala 1999).

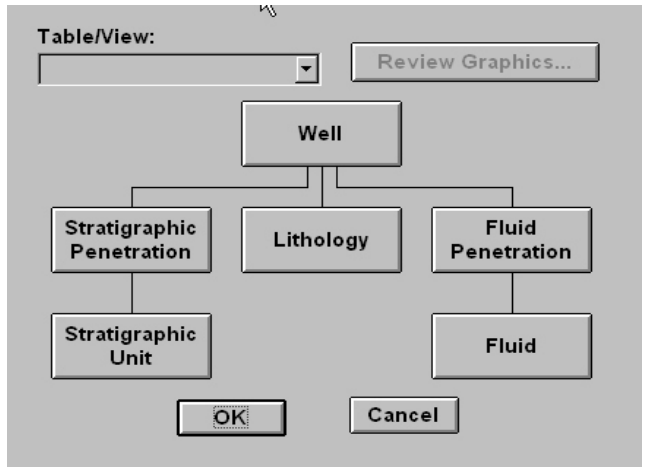

Figure 2. The table layout according to the Minimum Geology Sheme

4 DEPOSIT STRUCTURE MODELS

In this part of the work, models were made of faults, border areas of separated lithostratigrafic series as well as the mining workings network in the area of the planned waters forcing into rock mass.

Basing on the data gathered in the data base as well as the mining maps scanned and calibrated with the use of the MGE Modeller software, models of fault areas were made in the depth interval from 300 to -1300 m a.s.l. Then basing on the models, the coal mine area was divided into a number of tectonic blocks.

The subsequent stage comprised the construction of lithostratigrafic series border areas. Basing on the collected information, models were made in the area of previously separated tectonic blocks. The models were then combined to obtain comprehensive models of definite areas. The models were presented by means of the space oriented grid network and structural maps (Figure 3).

In the final stage, a three-dimensional model was made of mining workings network situated in the area of waters forcing to the rock mass.

5 HYDROGEOLOGICAL MODELLING

The hydrogeological modelling was carried out by a team lead by B. Dembski. The task was done by means of the *Visual Modflow* software, which is an integrated software package for numerical modelling of waters and pollutions flow.

The simulation aimed at making computation for the case without taking into account fault zones as well as for two variants of hydraulic conductivity of fault zones to assess their impact on waters inflow at the level of 500.

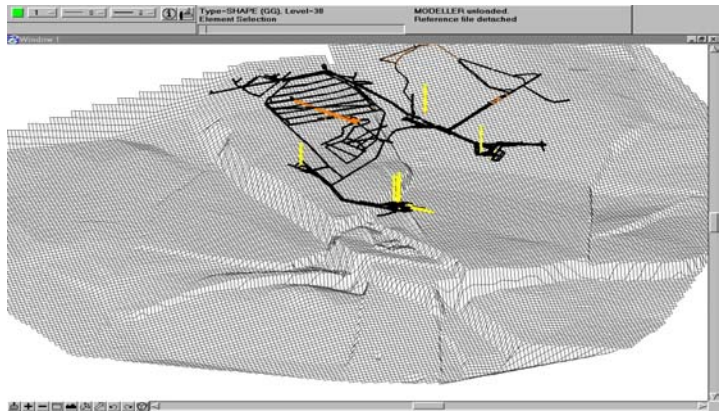

Figure 3 A fragment of the "Jaworzno" coal mine against the background of the ceilingmodel the Upper Silesian Sandstone Series (height enlarged x2)

The hydrogeological model covered the mining area of the "Jaworzno" coal mine with a slight extension to the north, north-east and west. The model reflected three lithologic series occurring in that area – Cracow Sandstone Series (KSP), Mudstone Series (SML) and Upper Silesian Sandstone Series (GSP). Numeric computation was carried out for the settled state since at that-time stage of recognition there were not enough data to calculate time variables (Dembski et all 1998). Table 1 presents detailed model assumptions.

Table 1 Detailed assumptions for the hydrogeological model

Strata	Kx [m/s]	Ky [m/s]	Kz [m/s]	Porosity Coefficient
KSP	$4{,}7*10^{-5}$	$4{,}7*10^{-5}$	$4{,}7*10^{-6}$	0,13
SML	$4{,}5*10^{-7}$	$4{,}5*10^{-7}$	$1{,}0*10^{-8}$	0,06
GSP	$4{,}5*10^{-6}$	$4{,}5*10^{-6}$	$4{,}5*10^{-7}$	0,12

The following values were adopted as filtration parameters of fault zones:

Variant 1 lack of fault zones – homogenous aquiferous layers

Variant 2 fault zones defined with filtration coefficient values $K_{fault} = 4{,}5 * 10^{-4}$ m/s

Variant 3 fault zones defined with filtration coefficient values $K_{fault} = 4{,}5 * 10^{-5}$ m/s

The above approach was justified by the necessity to determine the impact of fault zones to the influx of underground waters to mining workings at the level of 500. The filtration coefficient values for the fault zones were adopted in the following way:

in variant 2 from two to three magnitude orders higher than rock mass filtration coefficients, in variant 3 from one to two magnitude orders higher than rock mass filtration coefficients.

The computation results analysis demonstrated that:

- results for variants 2 and 3 indicate more than ten times higher water inflows to workings than those identified during the field studies
- variant 1, in which fault zones were ignored, indicates inflows to workings only slightly lower than the identified ones
- the statement that faults do not make a hydraulic contact between individual modelled strata may be accepted as a summarizing conclusion.

6 MONITORING OF THE IMPACT OF SALINE WATERS FORCING ON THE ENVIRONMENT

Assumptions and preliminary analysis of waters distribution in the rock mass

It was assumed that the main symptom of forced waters migration to overlying strata will be the change of chemical composition of waters flowing to mining workings. Relict waters of the absorptive series (GSP) and of the pumped-in waters differed from those inflowing in respect of the chloride ions contents. The increase of the ions contents in flowing waters was accepted as an indicator of the natural environment interference.
In order to create a reference point for observing chloride ions changes in waters flowing into workings, models that presented the original state were made (Figure 4). They were created basing on measurement results collected for

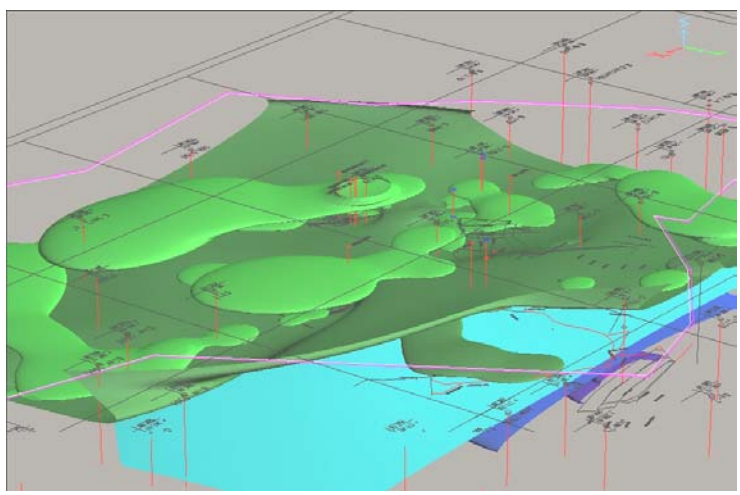

Figure 4 The hydrological zones borders area in the “Jaworzno” coal mine region (height enlarged x5)

several years by coal mine geological services. The results were placed in the data base. Spatial models of chloride contents presenting the state in years: 1993, 1996 and 1997 were generated with the use of the Voxel Analist software.

They were used for observation of waters relocations and waters distribution stability in intact rock mass. The analysis was carried out basing on block diagrams, intersections along assigned co-ordinates, maps for defined depths and other forms of visualisation made on the base of hydrochemical models (Figure 5).

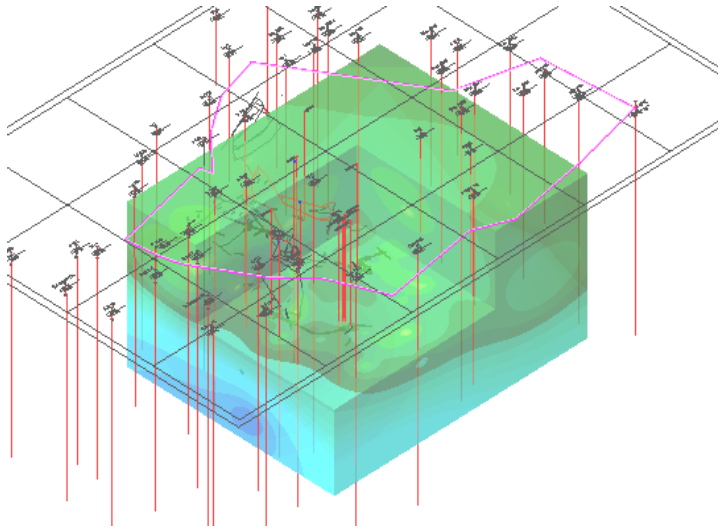

Figure 5 The block diagram of Cl ions contents in the research area 1996 (height enlarged x5)

The chloride ions variability was correlated with the rock mass structure. This was done by means of the structural models previously made and the localisation was facilitated by a mining workings model. It was found out that the presence of some dislocation zones is connected with the change of chemical composition of waters flowing to workings made near them (Figure 6). The waters were characterised by decreased mineralization and chloride contents, which testified of their migration from upper parts of the deposit. A distinct hydrochemical zonation of the area waters was also observed. Waters of strong mineralization (up to 140 000 mg/dm^3) accompanied absorptive strata. Upwards, within the package isolating absorptive strata from coal mine workings, a sudden waters desalting took place (mineralization up to 15 000 mg/dm^3). The analysis of the developed models demonstrated hydrochemical stability in the examined area and the lack of hydraulic contact between waters of absorptive strata and those of distant parts of the rock mass.

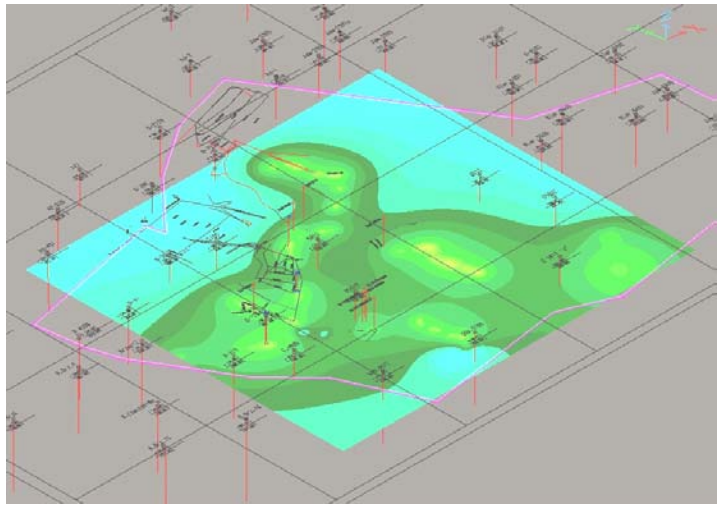

Figure 6 A map of Cl ions contents in waters of level 500 in the "Jaworzno" coal mine – 1993 (height enlarged x5)

Monitoring network

The monitoring covered the area neighbouring to injection bore-holes. Should any changes in the chemical composition of waters inflowing to workings had been found out, the observation area would have been extended. In co-operation with the coal mine hydrogeological services, 20 permanent measurement points were determined within the workings of the above defined area. The points were localised in the areas of identified water inflow to workings at the coal mine deepest level – 500.

The following criteria were applied to select the measuring points:

- maximum distance from injection bore-holes 1500 m
- workings accessibility
- neighbourhood of dislocation zones which might be a migration rout of forced waters to overlying strata
- spatial distribution uniformity of measuring points

Monitoring

Water forcing attempts were conducted in December 1998. The average field of two boreholes amounted to 1030 dm^3/min [2]. At the same time the coal mine geological services measured in definite time intervals the chloride ions contents in waters inflowing to the monitoring network points (Figure 7). Measurement results were currently introduced to – and stored in – the data base, according to the set symbol system. After each measurement series, coal mine employees

carried out chemism analysis based on collected data pertaining to waters inflowing to mining workings.

The analysis was carried out through the comparison in the data base of measurement results for the same points and with the use of hydrochemical models. A particular emphasise was put on the observation of waters chemism in the vicinity of dislocation zones. The above described models of chloride contents as well as deposit structural models were made use to this effect.

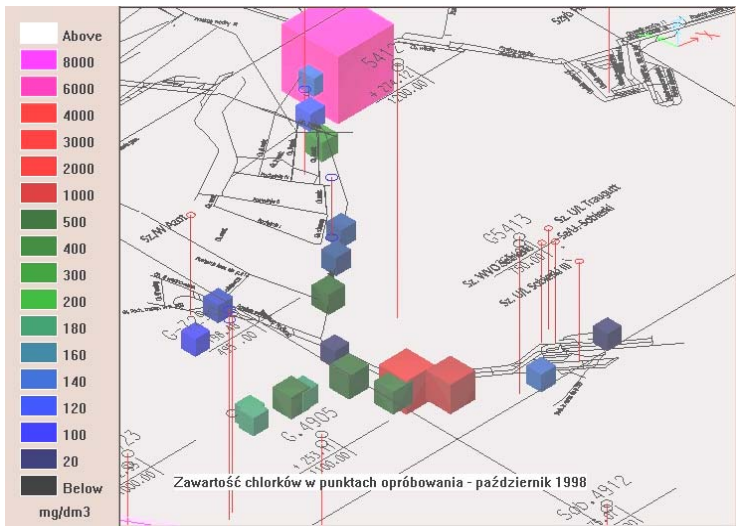

Figure 7 Location of monitoring network points against the background of the three dimensional scheme of mining workings (height enlarged x5)

No changes in the chemism of waters inflowing to coal mine workings were found out during the monitoring.

7 SUMMARY AND CONCLUSIONS

Results of the carried out work allowed for the following conclusions:

- The employed modelling method may be accepted as appropriate one. The models correctness was proved by results of drillings and field research.
- The complex monitoring system did not indicate any water forcing impact on the environment

The employed information processing tools allowed for:

- quick and simple access to information as well as for an option to update the information due to the application of the relational data base,

- computer-aided hydrological modelling,
- analysis of hydrochemical state of coal mine deposit waters on the ground hydrochemical modelling results,
- observation of chemical composition changes in the coal mine area against the deposit structure, which allows for localisation of hydraulic contact zones between water-absorbing strata and overlying ones,
- designing an easy-to-operate system for monitoring the impact of saline forcing to chemism changes of waters flowing to coal mine active workings,
- archiving the information obtained during the work.

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Zastosowanie komputerowych systemów modelowania i analizy danych dla potrzeb monitorowania zagrożeń, w związku z zatłaczaniem słonych wód kopalnianych do górotworu

Romuald Chryst, Michał Rupala

Streszczenie: W związku z prowadzonymi pracami, mającymi na celu redukcję zrzutu słonych kopalnianych wód do cieków powierzchniowych, firma PRG-W opracowała projekt iniekcji tych wód do piaskowców górnośląskiej serii piaskowcowej w obszarze KWK Jaworzno. Równolegle z robotami wiertniczymi wykonano prace nad komputerową symulacją zjawisk mogących towarzyszyć procesowi wtłaczania. Informacje dotyczące budowy geologicznej, parametrów geotechnicznych, hydrogeologicznych i wielu innych, wprowadzono do relacyjnej bazy danych. Następnie wykonano cyfrowe modele struktur geologicznych rejonu kopalni. Stworzono także przestrzenny model wyrobisk w rejonie zatłaczania. W kolejnym etapie przeprowadzono symulację komputerową zjawisk hydrogeologicznych, mogących towarzyszyć procesowi wtłaczania. Dla potrzeb monitorowania wpływu procesu wtłaczania na środowisko wykorzystano program Voxel Analist, który umożliwia pracę w przestrzeni wielowymiarowej. Pozwoliło to na wykonanie modeli hydrochemicznych dla poszczególnych okresów i obserwację zmian chemizmu wód w badanym obszarze.