HYDROGEOLOGICAL EXPLORATION OF LIGNITE BASINS.

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INTRODUCTION

The Geological Company in Wrocław plans, designs and executes hydrogeological exploration of lignite basins all over the country and produces respective reports. The hydrogeological exploration is carried out simultaneously with the geological exploration aiming at the estimation of lignite reserves. This is in compliance with state regulations on mineral resources. The hydrogeological investigation meets the suggestions and recommendations of Central Research and Design Institute for Opencast Mining Poltegor which is an organization responsible for mining, planing and designing and also, with those of the hydrogeological services in actually operated mines. The hydrogeological investigation carried out during geological exploration of lignite basins aims at:

- the delimitation aquifers within and around the explored basin and also, other structures which produce a water hazard for future mining operations;
- the determination of groundwater heads, thickness, spreading and depth of aquifers, their permeability parameters and also flow regime;
- the delimitation of recharge and drainage areas;
- the determination of groundwater origin, as well as of physical-chemical and qualitative characteristics of groundwater;
- the preliminary forcest of groundwater inflow to the pits and also, of the spreading of the cone of depression.

The information necessary to put this program into effect is received from drilling logs, laboratory tests and from direct field tests (mostly pumping tests). This information is supplemented to an essential extent by the results of radiometric survey and sometimes using other geophysical methods. In the hydrogeological investigation on lignite basins being mined and intended to be mined some phases can be distinguished i.e.:

- planning and designing of investigation
- the performance of field tests;
- additional correction to the direct and laboratory tests made upon continuous supervising

the interpretation and correlation of result, including their appropriate application and graphic representation which aims in the prediction of changes in a natural groundwater regime which are produced as a result of mining and dewatering operations including the effect of these changes on the interrelation between surface and groundwaters.

HYDROGEOLOGICAL DRILLINGS

A drilling system of wells for the direct tests depends on the depth of the investigated aquifer and on a number of aquifers intended to be investigated. In general, for drillings down to a depth of 150-200 m, where several aquifers are planned to be investigated, the percussion-rotary drilling system is used. On the other hand, when only one aquifer is to be investigated at a depth of more than 100 m, the well is drilled with rotary method. For drilling piezometers the percussion-rotary drilling rigs were used, but recently, they are replaced more and more by the rotary drillings. In the observation wells drilled by the percussion rotary method, four or five piezometric tubes are installed separately. When using the rotary drilling, each piezometric tube is placed in a separate well. In this case only one of the wells with full coring is drilled down to the bottom of the lowest aquifer. The other wells are drilled without coring in its immediate vicinity down to a depth of the subsequent aquifer. When planning and designing hydrogeological investigation, as well as their areal distribution and drilling sequence special efforts are made to:

- carry out pumping tests in all aquifers which affect substantially the water hazard;
- investigate in one test junction as large as possible number of water-bearing beds and aquifers;
- carry out pumping tests with as large as possible number of piezometers;
- provide a permanent monitoring system.

The recommended sequence of drilling is as follows: the observation wells are drilled first and then, the subsequent pumping wells are drilled starting from the external limits of predicted cone of depression towards the area of first dewatering. Such a drilling sequence allows to steadily increase the number of piezometers during pumping in the subsequent wells. The piezometric tubes left in the bore holes are an origin of permanent observation system to monitor changes in the dynamic water table during first phase of dewatering.

PUMPING TESTS

As mentioned above, a basic method of investigation are pumping tests. A most complete characteristics of the aquifer and the most representative hydrogeological parameters are obtained from pumping tests from wells surrounded with piezometers. However, due to the high cost, the number of such tests must be limited to a necessary minimum. This could be partially compensated by using the above mentioned drilling sequence. The number of pumping wells with piezometers and single pumping tests for each lignite basin is determined individually. Particular pumping tests arrangements consist of a pumping well and one or two observation wells (piezometers). It results from the practical experience that a distance between piezometers and pumping wells should not exceed 50 m for the first piezometer and 100 m for the second one. During hydrogeological exploration for dewatering planning somewhat different principles of designing and executing pumping tests are applied as compared to those used when estimating reserves for permanent groundwater intakes. The difference consists in a number of aquifers pumped in one well and in another method of pumping test running as well. When estimating reserves for groundwater intakes in single wells one aquifer or water-bearing complex is tested. Pumping is carried out with such a capacity so as to provide a minimum effect on the total volume of groundwater reserves during regular intake exploitation and also, to provide a quasi-stationary nature of groundwater table drawdown. On the other hand, during hydrogeological exploration of lignite basins, several aquifers are intaken in individual pumping well and pumping capacities are used in such a way so as to diminish the total volume of groundwater reserves with possibly maximum drawdown of non-stationary nature. To determine permeability parameters of lignite basins under investigation single-stage pumping tests are carried out in such a way so as to provide an increase of elementary drawdown value, S/Q, after a lapse of pumping time, at a maximum initial capacity (determined during cleaning pumping). Before starting with pumping test, so-called cleaning pumping is carried out, and hydraulic resistance of wells is measured. The cleaning pumping is intended not only to clean the well but also, to determine a maximum pumping capacity and to prepare labour organization during pumping test. The hydraulic resistance of wells is determined on the sixty minutes pumping (in a 3 to 4 - stage cycle). Irrespective of a type of pumping, the measurements of yield and water table drawdown rate are made, during first eight-hour time-period, with a frequency decreasing from one minute to thirty minutes. The subsequent measurements are carried out every one hour until the end of pumping tests. The measurements of groundwater table rise, back after pumping, are made with the same frequency. The above observation system provides a permanent monitoring and sufficiently accurate record of pumping course. At the same, the groundwater table drawdown is recorded continuously with limnigraphs installed in the piezometers. In the aquifers with low productivity, the hydrogeological tests are carried out by a method of water bailing (drawing). The permeability parameters determined with direct tests are characterized by a different degree of accuracy which is not always possible to be defined quantitatively. A main cause of errors is inherent in the inoccurate measurements and imperfect computational procedures, and in a limited range of their

application as well. First of these causes is possible to be cleared away by using more sensitive measuring devices and by increased frequency of measurements. To take away the next reason a critical approach is required to the selection of computational formulas, and a correct interpretation of testing results is necessary and also, and adequate procedure for calculation must be used. The comparable results can be obtained quite quickly by using equations of non-stationary inflow for the period of groundwater table rise after direct pumping or bailing. A frequent cause of errors committed in the interpretation of pumping tests in single wells is that due to neglecting initial observations which is often explained by an especially strong influence of the resistance of near-filter zone in this period.
It results from our experiments carried out within the lignite-basins investigation that the influence caused by the resistance of near-filter zone on the shape of drawdown curve is absolutely overestimated. On the other hand, the influence effected by the capacity of well itself is under-rated. The capacity of well plays particularly important role when testing aquifers of low permeability where, at relatively deep drawdown, only low yields are achieved. Then, substantial deformations of drawdown curves are the case, and their fitting requires a long time-period of observations, or a suitable method of computation is to be used taking the influence of well volume itself into account. Method of interpretation, which do not take the volume of well into consideration may be used only for final portions of the curves of water table drop-down and rise, when a condition $\frac{v(t)}{Q \cdot t} < 0.05$ is met.

Where: v(t) - water outflow from a well after starting with pumping, or water inflow after it has been stopped;

a - pumping capacity;

t - time counted from starting with pumping or its stoppage.

In such a way, however, the relevant hydrogeological parameters of an investigated aquifer are not always possible to be obtained. It is possible only when a complete well is the case, and the spreading of aquifer is unlimited.
If an aquifer of unknown thickness is pumped partially only its transmissivity (T) can be determined basing on the final segment of drawdown curve. On the other hand, to compute the coefficient of permeability (k), methods which take capacity of well into account have to be used. In this case it is possible to make use of the initial segment of the curve. In our practice, most frequently used procedures for computation of permeability are graphic-analytical methods, (i.e. method of logarithmic approximation, integral and operational ones), and analytic methods as well. An essense of integral and operational methods is in such a transformation of non-stationary flow equations so as to replace them,

as a result of their integration, by drawdon pulse equations. The drawdown pulse - J(t) depends here on the water volume - V(t) exactly in the same way as drawdown - S(t) depends on the yield Q(t). In respect of figures, the drawdown pulse is equal to a surface limited by the drawdom curve and X-axis (t). This surface is computed by planimetering or analytically using any method of numerical integration (f.ex. trapezoidal integration). The drawdown pulse values plotted on a semi-logarithmic diagram determine a straight line. Like in the method of logarithmic approximation, parameters of an aquifer are computed basing on the rectilinear segments. As distinct from semigraphical integration, the analytical methods consist in such an interpretation of drawdown curves (drawdown pulse) so as permeability parameters will be possible to be computed without transformation of these curves into the semi-logarithmic co-ordinates (f.ex. method of successive approximations, method of field ratio, etc.). A particularly important advantage of methods under discussion is possible interpretation of pumping tests results when the course of drawdown curve is disturberd for various reasons (e.g. that of a variable yield).

OTHER METHODS

To recognize and to prove hydrogeological conditions the laboratory test of rocks and water are made, apart from those made on site. The laboratory test of rock properties consist in:

- making particle-size analysis of loose soils;
- the determination of porosity;
- the determination of storage coefficient (specific yield) by centrifuging.

The tests of water properties consist in making full chemical analysis, and bacteriological analysis as well. In solving hydrogeological problems when investigating lignite basins the radiometric tests are very helpful. They consist of:

- single-well measurements of the dilution of radioactive tracer which provide information on the directions of flow, as well as horizontal and vertical components of a vector of ground water flow velocity are determined;
- two-well examination of the concentration of radioactive tracer (f.ex. radioactive isotope J^{131} or non-active bromide ion Br^-) to determine effective porosity, water flow velocity in the dynamic conditions and hydraulic connections between aquifers;
- measurement of natural tritium content enabling the origin and age of groundwater and also, groundwater - recharge areas and infiltration rate to be determined;
- determination of the micro-chemical composition of groundwater by so-called RAA method (reactor activation analysis).

As a rule, the micro-chemical composition of water is determined along with the measurements of natural tritium contents. These measurements provide with mutually complementary data. The simultaneous determination of characteristic features of chemical microcomposition in the surface waters and in aquifers allows to find hydraulic connections between those waters and also, flow ways. It helps also in pollutants(municipal and intustrial) migration identification to the groundwater. In solving hydrological problems, methods of mathematical modelling are used more and more commonly. The analytical solutions of hydrogeological problems require a far-reaching simplification and schematization. They make rather insufficient allowances for the shape of groundwater migration area, heterogeneity and spatial variation of hydrogeological parameters. Besides, the analytical evaluations of groundwater flows, as a function of time, are extremely labour-consuming. Therefore, methods of computer modelling are used more and more frequently because they make possible to:

- reflect natural hydrogeological conditions,
- determine hydrogeological conditions in more detail by solving tasks by the inverse way;
- study groundwater balance, and to calculate groundwater resources;
- forcast changes in the natural hydrogeological conditions of the natural environment as a result of dewatering.