WATER INTAKES IN UNDERGROUND MINES AFTER THEIR CLOSURE

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ABSTRACT

With reference to the characteristics of the basic water-bearing series, drained by coal mines, the kinds of existing water intakes in coal mines have been described as well as the influence of stopping the pumping system of a mine on the water intake alimentation has been determined. The scope of observed changes of chemical composition of water in intakes situated in mine workings in various geological and mining conditions has been described. The principles of location and protection the water intakes in underground workings after mine closing has been presented.

MINING - INDUCED DRAINAGE OF AQUIFERS

In the Upper Silesian Coal Basin area, in view of the scope of the drainage and the quality of waters inflowing into mines, two major hydrogeological systems can be distinguished. In the one, impermeable formations limiting the draining ability of mine workings into which mineralized Carboniferous waters are inflowing overlie the Carboniferous strata. In the other, due to the lack of impermeable formations, the mining operations being conducted in the Carboniferous withdraw water not only from the Carboniferous rock mass but also from the Triassic and Quaternary formations that contain waters of lower mineralization level.

The Quaternary water - bearing formation includes sandy and gravel sediments with clayey and silty intercalations. The thickness of the Quaternary sediments varies between several and several tens of meters. The variation in water-bearing strata sedimentation development made the Quaternary complex discontinuous and composed of a number of saturated layers. Sandy and gravel layers filling the buried river valleys form the largest deposits. In the industrialized areas, this Quaternary formation, being mostly outcropped, is affected by the organic and inorganic contamination.

The Triassic aquifer occurring in the northern part of the Basin is fractured and karstified and includes a series of carbonate formations. This horizon is split. The upper part is composed of the Muschelkalk (or the Middle Triassic) beds 60 to 80 m thick and the lower part contains the Roet (or the Upper Bunter Sandstone, or the Upper part of the Lower-Triassic) cavernous limestones and the marly and dolomitic sediments 30 to 60 m thick. In addition, a discontinuous water-bearing formation consisting of arenaceous sediments of the Lower Bunter Sandstone age (or the lower part of the Lower Triassic) also occurs there. It overlies the Carboniferous and has completely been dewatered by the hard coal mining activity. In the lower part of the horizon the static water resources of the Muschelkalk formation have completely been extracted as a result of the exploitation of the zinc and lead ore deposits. The water table has been lowered to the level of ore mine workings the dewatering of which is continued despite the completion of mining in order to guarantee safety of the underlying coal mine workings.

The Triassic waters as far as the physico-chemical and bacteriological compositions are concerned of very good quality and are often potable without treatment. However, such waters chiefly occur in the areas where no zinc and lead ore mining has been conducted. The mineralization of waters pumped out from the ore mine workings varies 2,5 to 2,7 g/dm^3 and their chemistry can be distinguished by the varying contents of the following components: SO_4^{2-} from 1,2 to 1,3 g/dm^3, Zn from 14,0 to17,0 mg/dm^3 and Pb 0,02 mg/dm^3. Waters from these workings are discharged into a river after their zinc content has been reduced to 0,4 to 2,0 mg/dm^3.

Coal mine drainage of the Triassic aquifer is of indirect character. Mining with caving under the Triassic strata has occasionally brought about extensive failures of the Carboniferous roof rocks reaching the floor of the water-bearing formations. In such cases, water inflowing into mine workings was intense and permanent. Under favourable mining and geological conditions such water outflows were managed and recovered.

The chemistry of the Carboniferous waters varies depending on their occurence depth and thedegree of isolation of a hydrogeological structure from the infiltration of surface and meteoric waters. The low mineralized waters of infiltration origin only occur in the zones of active exchange of waters that reach a depth of 250 m in the areas that are hydrogeologically outcropped. The chemistry of Carboniferous waters recharged by the infiltration waters and drained by the mine workings mostly depends on the length of their circulation paths in the post-mine workings. The general mineralization of these waters varies from 0,25 to 1,5 g/dm^3; the mean chloride content is several dozen mg/dm^3 and the sulphate content is from several dozen mg/dm^3 to more than 1,0 g/dm^3. The waters flowing through the old workings can, in addition to a higher sulphate content, contain organic contaminants and iron and manganese concentrations significantly exceeding the quantities acceptable for potable waters.

Below the waters infiltration zone in the Carboniferous and in the regions where this zone is hydrogeologically covered the mineralization of Carboniferous waters increases with depth. In the zone of intermixed waters the mineralization reaches a value of about 35 g/dm^3 and in the zone of relictic waters it exceeds 200 g/dm^3.

TYPES OF WATER INTAKES IN MINE WORKINGS

Intakes in active workings

The water extraction in mine workings includes the intakes of waters gravitationally outflowing from the workings that form the drainage system of the Quaternary and Triassic water-bearing strata overlying the Carboniferous. The drainage zone of a lesser extent can be formed by the individual passageway workings that are usually stopped due to the intense water inflow from the water-bearing strata or tectonic deformations intersected by the workings. The drainage zone can occasionally be enlarged by the draining boreholes drilled to increase the intake output or by the boreholes drilled for other purposes but properly adapted for draining such as the exploatory and protection holes.

Water intakes are usually located at the highest opening levels from where the water is withdrawn onto the surface independently of the main drainage system. The way the water is extracted from the workings mainly depends on the location and intensity of inflows. In the case of the small and dispersed inflows the workings into which the water is inflowing are sealed off by water dams. Next, the water is withdrawn through the pipeline to a storage reservoir near the shaft or directly onto the surface. The intakes of waters inflowing from the stopped post-mine workings that usually form considerably vast drainage zones of overburden strata are of similar type. When the inflow area is located far away from the shaft then in order to prevent water pollution the water must be withdrawn by the pipeline to a storage reservoir near the shaft.

Well-intakes of water from the abandoned flooded mine workings

Water extraction from the old water logged mine workings by means of well-intakes is less complicated than by means of intakes and pumps located in underground workings.

An example of the potable water intake from the flooded post-coal mine workings is the Brzezinka water intake which has been recovering water from the workings of the abandoned coal mine since 1928. This mine had exploited coal seams in the highly saturated Laziskie strata sandstone series at a depth of 200 m. The aquifer of this series is recharged by the infiltration of surface waters and the Quaternary water-bearing formation waters. The water is recovered by means of the well boreholes and filtered along the cross-cut length and the overlying sandstone bed. Only one well was exploited at a time and after it had technically been used up another was drilled. The intake water is characterized by the significantly constant chemical composition /Fig.1, A/. The water intake output is stable enough and varies between 6 and 7 m^3/min.

The Rozalia pit intake withdraws water from the abandoned zinc and lead ore mine workings. The mine had been active by the end of the last century but was flooded as a result of a disastrous water inrush. Since 1885 the water had been pumped out from the Muschelkalk age horizon, at first by way of one shaft and then by two shafts, each about 50 m deep. Next, the wells 135 m deep were drilled in the shafts by way of which the waters from both the Muschelkalk and Roet horizons were extracted and in 1950 the intake began to exploit only the Roet horizon. In 1993 the withdrawal of water was terminated because of its poor quality. The water intake output was initially 30 m^3/min and from 1940 it was gradually declining down to 12 m^3/min in 1950 and 3,1 m^3/min in 1993. The drop in the intake output after 1950 was caused by the failure of roof rocks induced by the mining with caving of the coal seams in the nearby coal mine combined with the rapid inrush of the Roet strata waters to mine workings. The Rozalia pit intake pumped waters of a more and more deteriorating quality. During a period of 13 years the water mineralization increased from 1042 to 2142 mg/dm^3 /Fig. 1, B/. Since 1989 the chloride content has increased threefold compared to the period between 1981 and 1985. This was probably caused by the high pollution of the environment and the conditions favourable for the fast migration of industrial pollutants from the surface to the Triassic aquifer.

Water intakes in shafts

The shafts are the specific mining excavations that intersect water-bearing strata and that is while their lining must be watertight and strong accordingly. Actually, however, the majority of shafts experience leakages and slight water inflows from behind the lining mostly in the zones of water-bearing strata occurrences.

In order to control the water inflows and to reduce its pressure behind the shaft lining along the intersection lengths of the highly saturated strata the local drainage of the rock mass, also playing a role of the water intake, has been used in the mining practice.

In one of the shafts of the coal mine, which was being sunk during the period from 1905 to 1915, 203 boreholes penetrating the lining at the shaft depth interval of from 30 to 80 m have been drilled. At first, the Quaternary water-bearing strata were drained with these boreholes and after the dewatering had been completed, the underlying Lower Bunter Sandstone strata were drained. The cumulative pipelines gravitationally were withdrawing water to a storage reservoir and then to the pumping station at a level of 220 m. The intake output amounted to about 0.8 m^3/min and the water mineralization varied from 570 to 870 mg/dm^3. Now, after the coal mine closure that shaft has been converted into the well intake.

The shafts usually are converted into well intakes when during their sinking very saturated layers are encountered the inflows from which makes further mining operations impossible. More local problems arise when the shaft sinking operations are crossing the Triassic carbonate series forming the fractured and karstified water-bearing horizon. The BDS shaft sunk during the period from 1910 to 1914 to a depth of 116.5 m was stopped in these layers because of the rapid inrush of the Roet strata waters. In the initial phase in 1914 the intake output was about 15 m^3/min and then it declined with time to 5.4 m^3/min in 1951, to 2.6 m^3/min in 1965 and to about 2.0 m^3/min when the intake was closed in 1973. The decrease in the amount of water extracted from the BDS shaft was also associated with the deterioration of its drinking quality. During the period from 1960 to 1970 the mineralization of the water and the content of the Cl^- and SO_4^{2-} ions gradually increased /Fig.1, C/. Since 1970 the changes in mineralization showed considerable fluctuations with the general tendency to rise in values. And so in 1973 the pumping of water was ended.

CHANGES IN QUALITY OF WATERS PUMPED IN INTAKES LOCATED IN MINE WORKINGS

A significant increase in general mineralization and in the Cl^- and SO_4^{2-} ions content of the waters inflowing into the intakes located in mine workings has occurred /Fig. 1, B,C/, which brought about termination of the withdrawal of waters form the Rozalia pit and BDS shaft intakes. This has been caused by the continuous local pollution of the Triassic waters produced by the expanding sulphide oxidation zones in abandoned zinc and lead ore mines and the migration of pollutants washes out from the industrial waste material dumps located on the surface.

The fluctuation of the mineralization varying from 500 to 1000 mg/dm^3 has been observed in the intakes of waters from post-mine workings in the hard coal mines draining the Triassic water-bearing horizon beyond the area of the zinc and lead ore mining. The Cl^- ion content varies from 50 to 120 mg/dm^3. The variation range of the analyzed parameters is not big and its anisotropic character may be associated with the periodically changing conditions of the supply and circulation of waters in gobs. Taken as a whole, an increase in general mineralization is accompanied by an increase in the SO_4^{2-} ion content.

A relation between the mineralization at the Carboniferous and Quaternary waters drained by the intakes in mine workings and the stratigraphic and lithological structure of the layers intersected by post-mine workings is observed. The general water mineralization in the intakes that drain gobs of the Laziskie series beds varies from 550 to 750 mg/dm^3 and in the intakes that drain gobs of the Orzeskie series beds this value varies from 900 to 1100 mg/dm^3. The Cl- ion content in the waters from gobs of both the stratigraphic series is approximately similar in values varying from 50 to 150 mg/dm^3. The quality of pumped waters from the intakes located in mine workings, in addition to mining and geological factors, mostly depends on hydrogeological conditions in the intake supply areas. That is because the above mentioned intakes drain the infiltration water zones which are characterized by the low mineralization water dynamic resources and which are under the surface pollutant migration hazard.

THE PRINCIPLES OF LOCATING AND PROTECTING WATER INTAKES IN POST-MINE UNDERGROUND WORKINGS

The general principles of protecting the existing water intakes and constructing new ones in mines being under closing operations should be as follows:

- precluding the manageable low mineralization waters from intermixing with the mineralized waters,
- maximum limitation of the number of maintained workings left after the mine abandonment.

The first requirement can be met only in the partially flooded mines where the system of workings draining the low mineralization waters is located above the maximum wellhead of the gob confined water.

The second requuirement is of great importance from the view point of the profitability and exploitation of water intakes. Thus, the water intakes in abandoned mines should be located as close as possible to the shafts with the pumping stations equipped with appropriate ventilation systems allowing one to carry out routine services. This requirement is unnecessary in the shafts converted into the well intakes with suspended pumps. Such a solution is more useful because it also allows readjusting to the water table variations in abandoned workings. In Fig. 2 are shown the principles of the water intake functioning in a partially flooded mine. The waters of higher mineralization at deeper levels are inflowing into the underlying workings of neighbouring mines. The shaft with a closely located fresh water pump station should be filled and closed up to the station level.

After the mine closure the shafts can be converted into well intakes of substantial output. The occurrence of a rich water-bearing horizon in the shaft's geological profile and the filling of a lower part of the shaft with an impermeable material are the main requirements for constructing such intakes. Waters can inflow into the intake from the workings situated at the water-bearing horizon levels as well as directly from the water logged strata after they have been opened enough by the shaft lining. In order to increase the intake output the drainage boreholes should be radially drilled from the shaft.

The conversion of abandoned shafts into drainage well intakes is particularly recommended in the strongly recharged water-bearing horizon areas as, for instance, near the river water infiltration zones, water logged buried river valleys, etc.

The shafts into which the waters inflow either through the network of shallow post-mine workings that form a vast drainage zone recharged by the direct infiltration of atmospheric precipitation or through the rich Carboniferous overburden water-bearing strata also exhibit the drainage intake features (Fig. 3).

The completion of dewatering of mine workings and their partial or entire flooding will make the cone of depression, developed due to the long-term water withdrawal from the aquifers, filled with water. The degree of the static water resources restoration in aquifers now being drained depends on the well head stabilization after the workings have been flooded. The possibility of exploitation of water-bearing formations in the abandoned mine areas should be determined based on the complex hydrogeological study describing the consequences of the completion of dewatering of mine workings and the impact of their flooding on the natural environment.

On designing the intakes in the abandoned mine areas the intake protecting zones should be determined and investigated with the purpose to protect them from the biological contamination, the deterioration of the water physico-chemical properties and the output decline. In the intake protecting zones the disposal of waste materials into the workings or onto the surface, which might adversely affect the water intake quality, is not allowed.

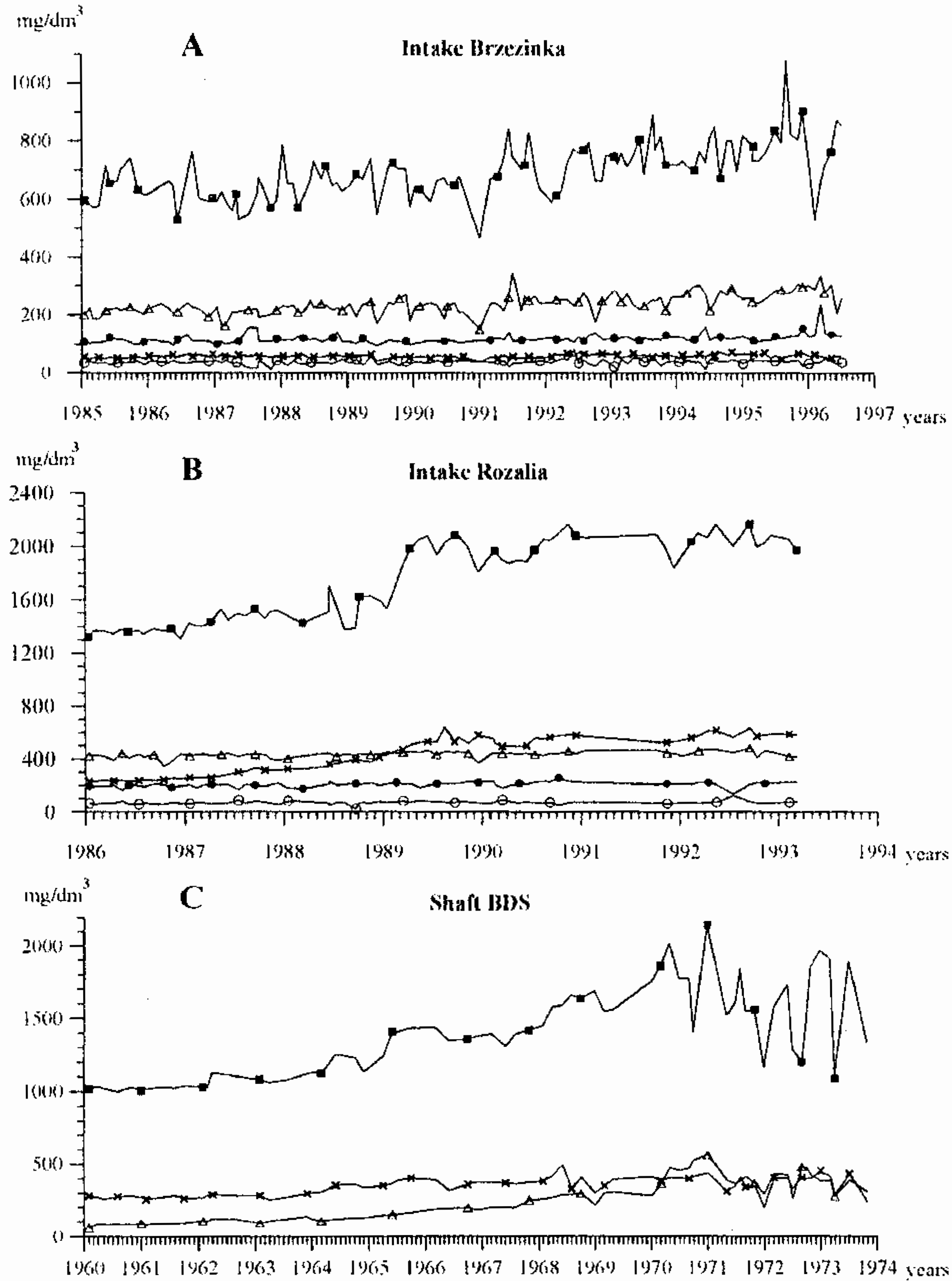

Fig. 1 Changes of quality of waters pumped in intakes

M Ca^{2+} Mg^{2+} Cl^- SO_4^{2-}

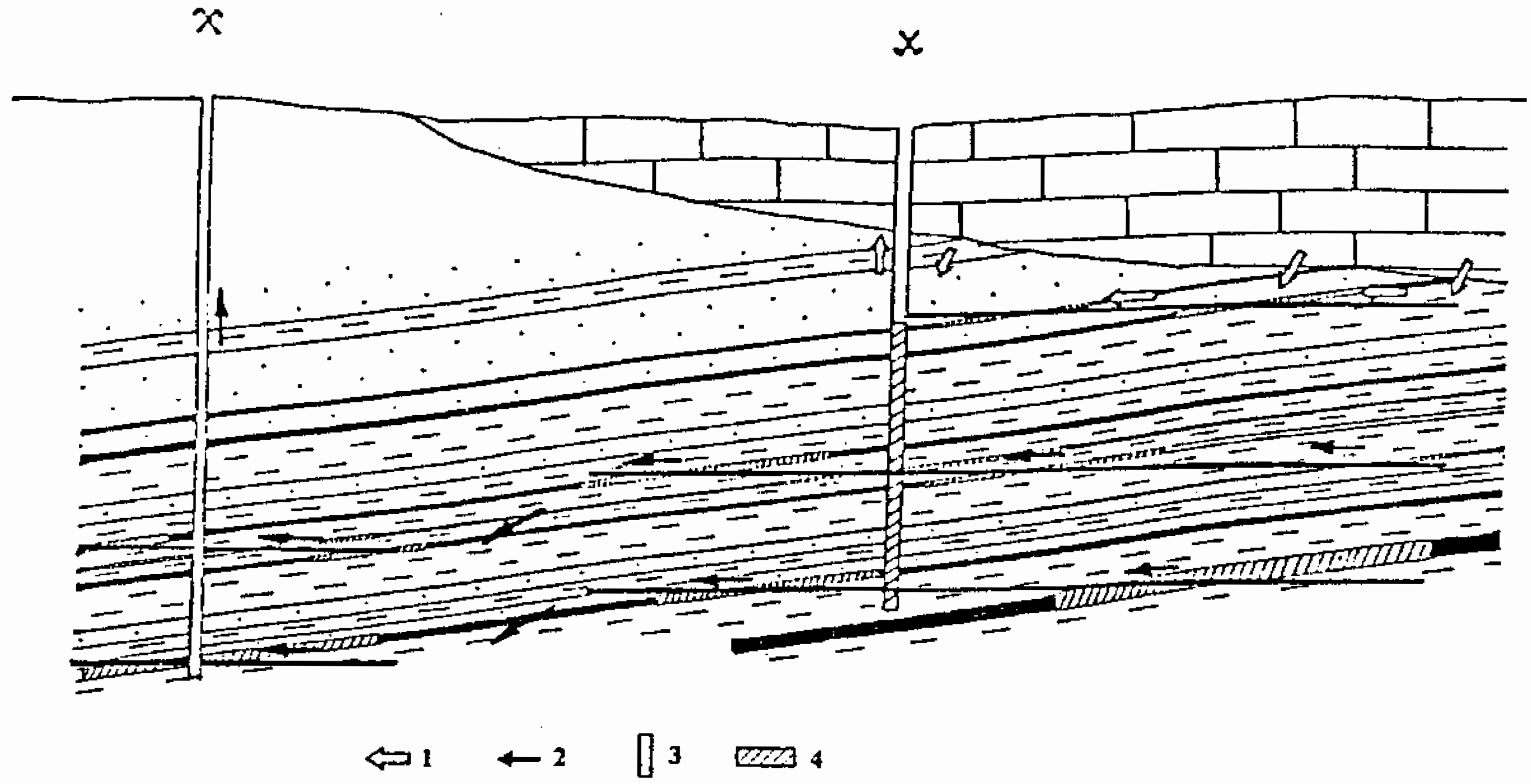

Fig. 2 Scheme water intake in a partiolly flooded mine.
1 - water of low mineralization 2 - water of high mineralization 3 - liquidated part of shaft 4 - gob

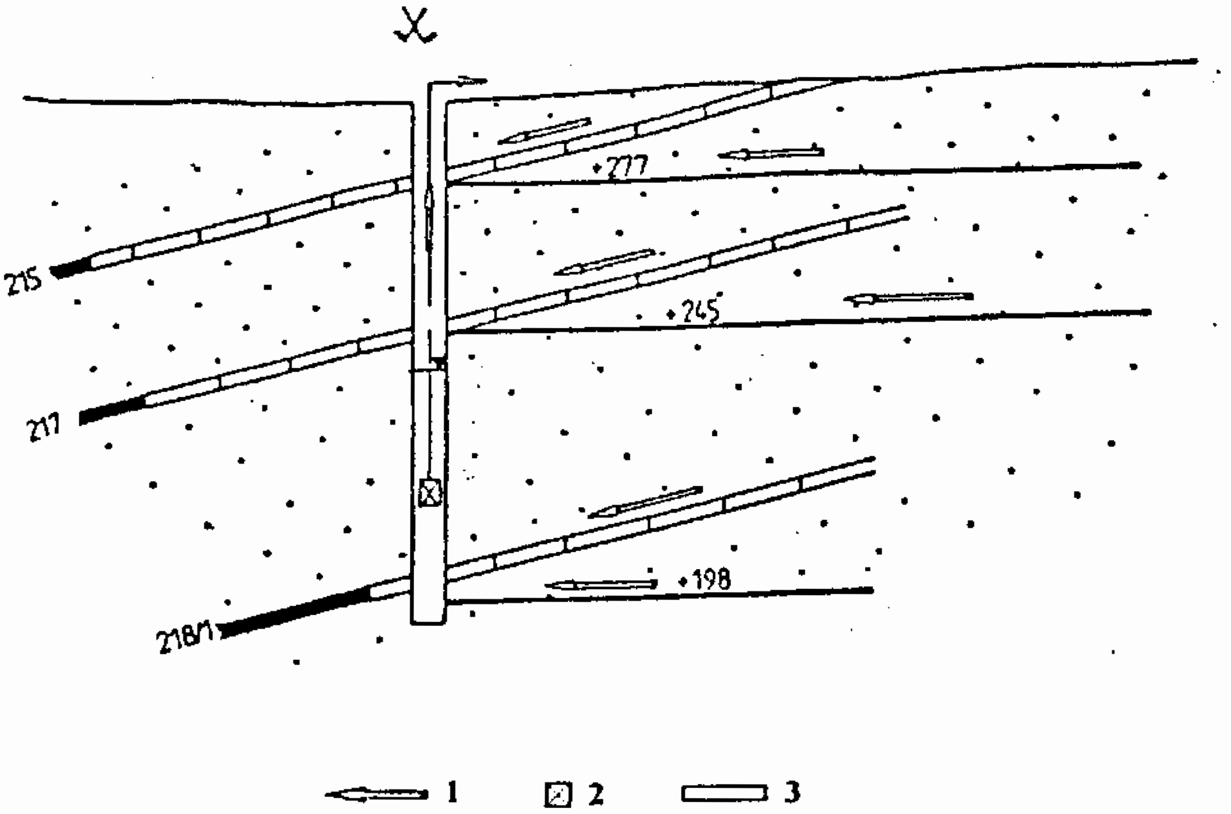

Fig.3 Scheme water intake recharged by the direct infilration.
1 - water of low mineralization 2 - suspended pump 3 - gobs