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PROTECTION SYSTEM AGAINST WATER AT THE OPEN PIT GACKO WITH COLLECTIVE WATER COLLECTOR AS THE CAPITAL STRUCTURE

Abstract

Protection of the open pit against water is very important, especially if the open pit is located in the complex conditions regarding protection of the open pit against water. To reduce the investments, it is proposed to define the protection system of the open pit against water for a longer period. In the specific case, the technological system of protection against water was considered at the open pit Gacko with construction the canal system with a The Cumulative water collector. The aim of developing such system is the water directing water the river Musnica riverbed and effective protection of the open pit.

Keywords: *water collector, canal, protection against water, open pit Gacko*

INTRODUCTION

Gatačko field (karst field) is the intermountain depression filled with Neogene sediments formed in the relaxation phase of the field after cessation the directed tectonic pressures (Oligocene - Miocene). Gatačko polje and coal bearing Neogene sediments are located in the extreme southeast of the Republic of Srpska on the border with Montenegro. Three quarters of the field are covered with the Quaternary sediments beneath which are the Neogene formations in the area of about 40 km^2. Gatačko polje is mildly ruffled plateau that greatly changed its shape with construction of the open pit.

The river Musnica is the largest water flow that passes across the field. It enters into Gatačko polje in the east of Avtovac, and leaves it at Srđević where gradually sinks. Right tributary of the river Musnica are the river Gračanica and Gojković stream (with its tributaries) flowing directly through the productive part of the coal bearing Gatacki basin, and but flows and amounts of water in them have a major impact on the open pit mining of coal and system of the open pit protection against water. Flows in all three surface flows are a direct consequence of climate conditions in the region, and rainfall in certain seasons.

From late fall to early spring, the lowest, southern and southwestern parts of the field are often flooded by a pillar of water, depth of up to 0.6 m, which (by a steep gradient) decreases immediately after cessation of heavy rainfall. Flooding arise due to the formation of natural pre-abyss retention, as the common abyss zone does not exist (due to the existing geological situation) in the lowest southwestern part of the field, so the gorge near Srdjevici cannot, in a short term, to miss the great storm water collected by the river Musnica.

The open pit Gračanica - Gacko was opened in 1978 in the western part of Ga

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tacko polje. Mining at the open pit Gračanica took place in the Field A, Field B and part of the Field C.

To enable the undisturbed coal mining, it was necessary to relocate the said watercourses. The reason for relocation is too great proximity of the riverbeds of watercourses to the open pit contour, or the watercourse is on the site where the planned progress of works was planned on deposit mining.

On two occasions, the mining was terminated due to the reason of water penetration from nearby watercourses into the open pit, more precisely into the Field B of the open pit Gračanica, as follows:

- in 1998 when, when the open pit contour was broken by the water from the stream Gojković,
- in 2013, when the open pit contour was broken by the water from the river Musnica (with Gračanica).

In the previous period due to the needs to develop the open pit Gacko, the regulation of the river Gracanica and relocation a part of the Gojković stream were done, as well as relocation the riverbed of the river Musnica (phase I). Currently the river leaves Gatačko polje through the regulated flow of the river in the zone of the road Gacko - Kula ("Bypass"). Due to the development of mining operations, no later than 2024, it is necessary to complete the relocation of the river Musnica and implement the second phase of relocation.

By development the mining activities and mining in the south-east section of the excavation front, the old riverbed of Musnica is cut and loses the natural recipient for water drainage from the open pit Gacko-Central Field. The solution to this problem is a condition for further mining.

Coal mining of the deposit Gacko takes place in complex hydrological and hydrogeological conditions and therefore a considerable attention and time should be given and to invest the financial assets for protection the open pit against water.

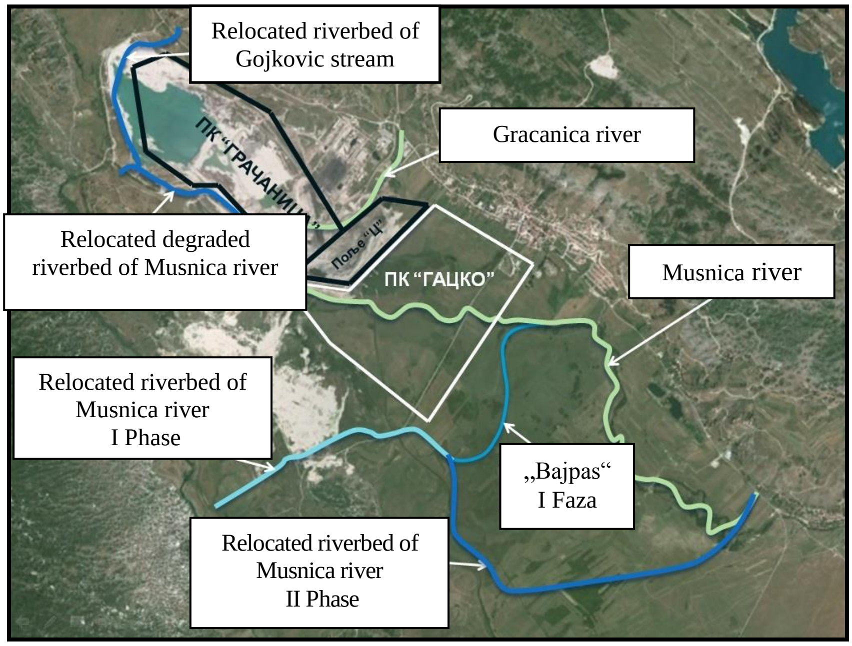

Figure 1 *Position of mine and major watercourses in Gatacko polje*

The protection system of the open pit against water among other facilities also includes development of the Collective water collector as the capital facility. Within work described in detail those parts of the drainage system that are related to Collective water collector.

The theme of this work is to construct a drainage system with the Collective water collector as the capital facility.

Analysis of the sizing factors of facility

In order to define the drainage system, it is essential to know the baseline of hydrogeological, geological, hydrological, geomechanical and mining technological parameters, then to realize a quality selection and sizing drainage the facilities for drainage the surface water and groundwater.

For selection the technical measures for protection the open pit on surface water, it is necessary to know the size and characteristics of catchment areas. The area from which water runs into the zone of the open pit represents a catchment area that is designated by the watersheds. Contours of the catchment area of surface and ground water as a rule do not have to match. Characteristics that affect the regime of surface water inflow from the catchment area of the open pit are: the geometrical shape of the catchment area, geological and pedological cover, high-altitude conditions, climatic conditions, density of watercourse streams in the catchment area, etc. In the planning process, an analysis of the size and basic elements of catchment areas that have a direct impact on the flow of surface water in the zone of the open pit Gacko-Central field. Figure 2 presents the position of catchment areas that gravitate towards the area of the open pit Gacko, and Table 1 presents the size of catchment areas of the open pit and their characteristics.

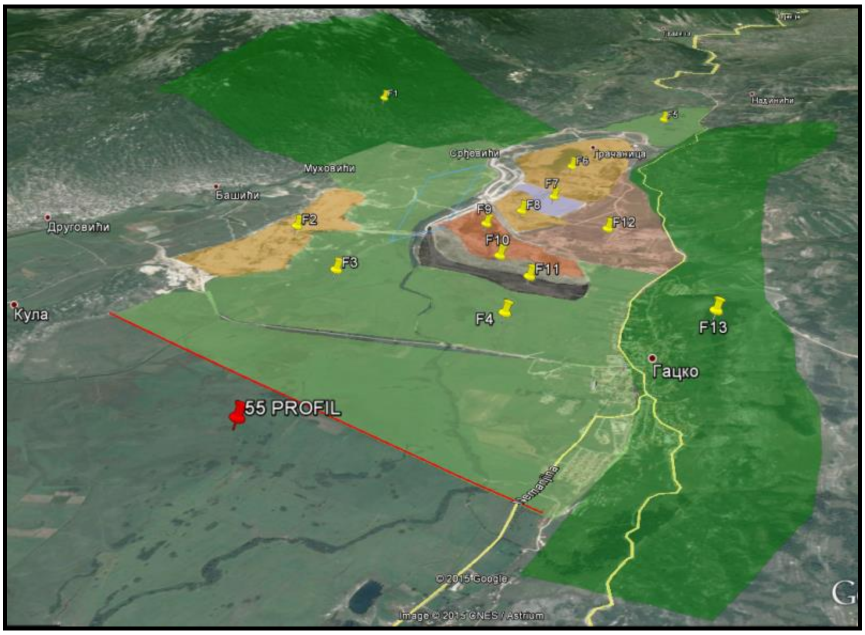

Figure 2 *Catchment areas of the open pit Gacko*

Table 1 *Size of catchment areas at the open pit Gacko*

Name of catchment area	F (km^2)	Volume (km)	VH (m)	VL (m)
F1 – Catchment area of southern mountains	11.70	14.70	500	2,700
F2 – External landfill	1.00	5.30	15	900
F3 – South part of plane	4.75	13.00	5	2,000
F4 – North part of plane	1.61	6.74	5	2,000
F5 – West part of plane	0.98	5.65	15	3,000
F6 – Internal landfill Field B	1.49	4.97	30	1,700
F7 – Ash landfill Field A	0.26	2.27	10	800
F8 – Internal landfill Field A	0.32	2.72	30	1,800
F9 – Current internal landfill	0.59	4.26		
F10 – Excavated area	0.34	3.83		
F11 - Mining front	0.34	4.29		
F12 – Industrial circle	1.44	6.32	5	3,000
F13 – Catchment area of norther mountains	7.80	18.00	100	1,800
F14 – Eastern flat part behind the road Gacko – profile 55	3.00	9.00	5	3,000
TOTAL:	**35.62**			

In the previous period all surface and groundwater, collected within the protection system of the open pit of water, were evacuated into the riverbeds of the rivers Musnica and Gracanica. All water from the area of the basin swell by the flows of these rivers to the west beyond the borders of coal basin. Despite the fact that the river Musnica was relocated, the old riverbed was so far used for the water evacuation. By designed development works at the open, the old flow of this river was cut, and it is necessary todirect all water in the area of the existing open pit and east of the front of works carried out in the new riverbed of the river Musnica. Based on the present situation in Figure 2, the catchment areas are seen with pouring water into this zone of the open pit:

- F2 – External landfill
- F3 – South part of plane
- F4 – North part of plane
- F9 – Current internal landfill
- F10 – Excavated area
- F11 – Mining front

Considering data from Table 1, the position of front works and facilities of drainage system, it is shown that out of total 35.62 km^2 actually is around 3.0 km^2 of the area from which the water inflows into the zone of drainage facilities that are directed towards Collective water collector.

For sizing the protection facilities of the coal open pits against surface water and groundwater, it is necessary to determine the so-called computational rain. They are determined by the analysis of probability the rain occurrence with certain intensity of duration. Computational rain or the amount of precipitation is calculated by the methods of mathematical statistics.

This processing is usually done by the specialized institutions (Hydrometeorological Institute, and similar), which determine the mentioned precipitation on the basis of pluviographic data. In the present case those are data of the Meteorological Service of the mine Gacko referring to the sixty-year return period and that meets the prescribed requirements for design the protection facilities of the open pit against water, and these values are:

- Maximum sixty-year 60-minute rainfall: 56.0 mm (lit/m^2)
- Maximum sixty-year 24-hour rainfall: 198.4 mm (lit/m^2)
- Maximum sixty-year monthly rainfall: 636.0 mm (lit/m^2)

- Average sixty-year annual rainfall: 1,615 mm (lit/m^2)
- Maximum sixty-year annual rainfall: 3012.5 mm (lit/m^2)

Protection system of the open pit against water

The previous drainage method is based on the fact that water that inflow into contour of the open pit has to be collected in two water collectors VS-C1 and VS-C2, where they are pumped by the system of pumps and pipeline into the river Gracanica. Evacuation of water, collected in the water collector VS-PZ1 (water collector within the Zone of roof coal), is carried out by pumping into the old riverbed of the river Musnica.

The new system requires that all water received at both limbs of the open pit (Central Zone and Zoneof roof coal) has to be evacuated into the river Musnica. To enable this, it is necessary to create a system of circumferential canals and Cumulative water collector (CWC).

System of circumferential channel is intended to prevent the additional water inflow from the catchment areas in the contour of the open pit. Water collected in canals are directed towards a common recipient Collective water collector. Some channels, in addition to the function of protecting the open pit from water inflow from catchment areas in the open pit contour, have the task to accept water that is pumped from the open pit contour and direct them towards a common recipient Collective water collector, where it will continue to send the collected water into the river Mušnica.

Circumferential canals, intended to prevent the inflow of water in the open pit contour, are:

- East Canal 1 (EC-1)
- East Canal 2 (EC-2)
- East Canal 3 (EC-3)
- East Canal 3’ (EC-3’)
- South Canal 1 (SC-1)
- South Canal 2 (SC-2)
- Austrian Canal (AC)
- North Canal (NC)

The North Canal has a function to accept all water flowing towards the open pit on the north side (Figure 2 - catchment area F13). It directs the collected water to the North water-collector (NWC), and from there into the river Gracanica.

The East Canal 1 is the main canal of the group of eastern canals. Its task is to take water from the catchment area, to receive water from the East Canals 3 and 3' collected in the Auxiliary water collector (AWC) (where it is transferred using the pumps and pipeline transferred to the East Channel 1) and directs them to a new riverbed of the river Musnica, more specifically to the "Bypass".

All water that has entered the Central Zone of the open pit are collected in a water collector (MWC-CP) and using the pump station with an installed pumps and piping system (required equipment is shown in Table 2) are evacuated into the South Channel 1. The pumped water, with water in canal from catchment areas, is directed towards the Austrian Canal. The Austrian Canal, besides water arrived from the South Canal 1, also has the water coming from the South Canal 2 (which is designed to accept water from the eastern part of the catchment area of the landfill) as well as water from the catchment area of the Austrian Canal. All water that gets into the Austrian Canal are directed to the Cumulative water collector.

Unlike the Central zone, water that are received at the Zone of roof coal are significantly simpler to evacuate to the Cumulative water collector. From the Zone of roof coal, the water that was collected in the water collector MWC-KS is evacuated directly into the Austrian Canal using a pumping station with the installed pumps and pipeline. The planned equipment is shown in Table 2.

The East Canal 2 is located directly in front of the front works in the Zone of roof coal, with the purpose to prevent the inflow of water in the open pit from the east side. In addition to the collected water, this canal is sized to accept, if necessary, the water that was collected in the water collector in the Zone of roof coal. All received water in canal is transported in the Cumulative water collector.

Table 2 *Pumping facilities of water collectors connected to the system of circumferential canal and Collective water collector*

Water collector	Pumps	No. of pumps	Power [kW]	Power of facility [kW]	Calculating - required capacity [l/s]	Installed capacity [l/s]	Pipeline Ø [mm]	Length of pipe-line [m]	Total length [m]
CWC	DH 86-50	2	500	1000	950	1000	350	430	860
	BS 2250MT	2	54	108		260	250	430	430
GVS-CP	CS 3240	3	275	825	470	558	300	810	2430
	BS 2400HT	2	90	180		102	250	810	810
GVS-KS	BS 2250HT	2	54	108	90	180	250	400	800

The backbone of this system is the Austrian Canal; it is sized to accept all water from the south side, i.e. water from the South Canal 1, South Canal 2 South, water that inflows from the catchment area around canal and collected water in both limbs of the open pit. Its original intention was to irrigate the agricultural land, while it is currently used as a canal for drainage.

This method drainage is anticipated to begin operations in 2017, so that in 2016 the drainage of the open pit is carried out on the current mode. The reason for this is the required time to construct the drainage facilities and purchasing the necessary equipment. All facilities that make up the drainage system are stationary. Figures 3, 4 and 5 show the designed status of works in 2017, 2020 and 2037 (the end of mining) and the position of drainage system with the Cumulative water collector.

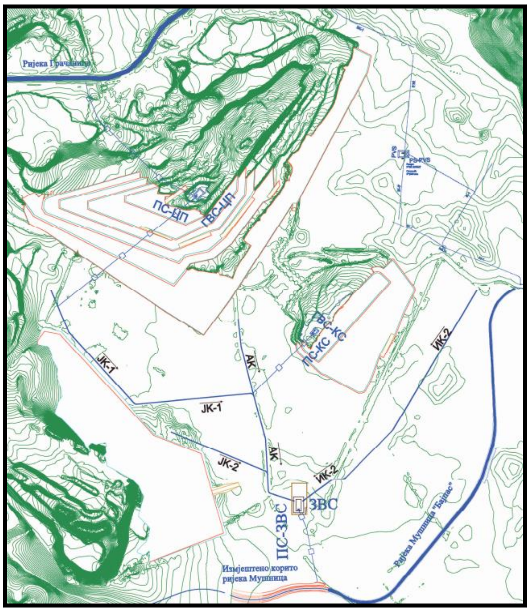

Figure 3 *Position of drainage facilities and system of circumferential canals and the Cumulative water collector in 2017*

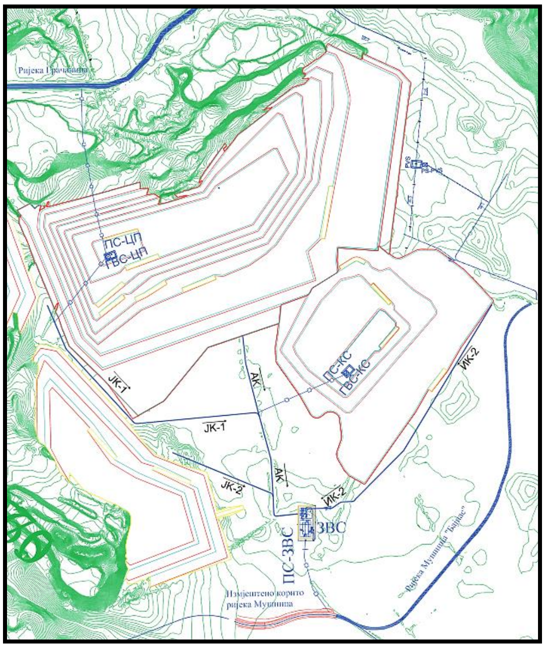

Figure 4 *Position of drainage facilities and system of circumferential canals and the Cumulative water collector in 2020*

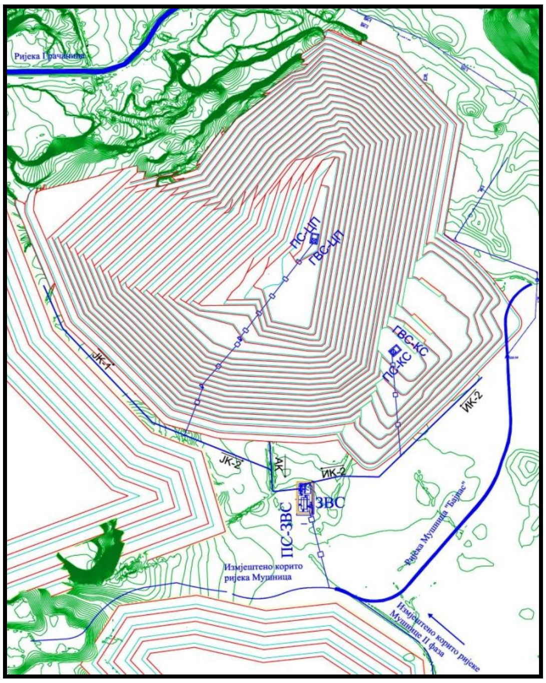

Figure 5 *Position of drainage facilities and system of circumferential canals and the Cumulative water collector in 2037*

The Cumulative water collector (CWC)

Due to the changes in direction of water evacuation in the Gacko basin, the gravitational connecting of predicted canals cannot be predicted in a new riverbed of the river Musnica, but it must be carried out by force. The main facility that allows this is the Cumulative water collector.

The Cumulative water collector is designed to accept water that inflow from the canal:

- East canal 2 (EC-2)
- South canal 1 (SC-1)
- South canal 2 (SC-2)
- Austrian canal (AC)

The surface from which The Cumulative water collector collects water is about 3.0 km^2. In addition to the water that inflows from the catchments areas, the water evacuated from the open pit is also collected in water collector. Maximum inflow of water into water collector is about 11 m^3/s.

Table 3 *Inflow of water into canals that flow into the the Cumulative water collector*

Canals	F Catchment (km^2)	Hourly intensity of rainfall (mm)	α drainage coefficient	Additional inflow (m^3/s)	Water inflow into canal	
					(l/h/m^2)	(m^3/s)
JK-1	0.50	56.00	0.40	0.47	11.20	3.58
JK-2	0.30	56.00	0.40	0.00	6.72	1.87
IK-2	0.60	56.00	0.40	0.00	13.44	3.73
AK	0.20	56.00	0.40	0.09	4.48	1.33
					Total:	**10.52**

Construction of water collector is planned to take place in two phases. The first phase of construction the Cumulative water collector includes excavation the Quaternary series and body of water collector. Works on the first phase of construction the water collector are foreseen for 2016. The second phase of the Cumulative water collector involves construction a settlement tank with overflow. The body of water collector and settling tank with overflow is necessary to coat to prevent water drainage from the water collector. Works on the completion of the water collector (II second phase) are foreseen for 2017.

Total volume of water collector is 36,700 m^3, although the quantity of excavated material would be much higher. For the reasons why the water collector is constructed, it was necessary to lower the water collector to 5m below the ground level, i.e. below the level of +940. In order to provide a sufficient maneuvering space for equipment that will work on maintaining the water collector, a space for installation the emergency pumps and other ancillary works at the level +935, a plateau is formed with a descending ramp. Dimensions of excavated area at the level +940 are 156.3·70.6 m, and the slopes at angle of 65º. From the level +935, the construction of a part of water collector is foreseen that should receive water from the canal and its volume is 36,700 m^3, out of which the volume of settling tank is 5,700 m^3, and a body of water collector 31,000 m^3. Dimensions water of collector are shown in Figure 6.

The area between the plateau at the level of +935 and the surface are predicted to be a reserve area for flooding, namely that in the event of heavy rainfall they can receive water that the pump cannot evacuate. Volume of this area is about 58,000 m^3. In order to enable the sinking of the area above the level of +935, the condition is that the plateau has no installed equipment that can be jeopar-dized by its immersion. The additional equipment will be stationed at the level +940.

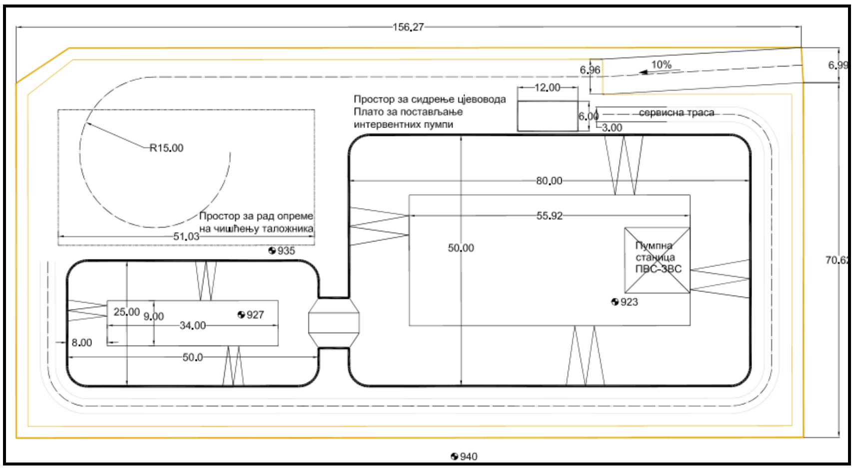

Figure 6 *Construction and dimensions of the Cumulative water collector*

Position, at which the construction of the Cumulative water collector was planned, by its geological characteristics meet the requirements for its development. Perhaps the most important thing about the choice for water collector site is that the water collector is constructed in homogeneous material, marl. After examining the geological base, it was found that a layer of limestone, developed in depth, in a given area is deeper than the anticipated depth of the water collector that can affect the functioning of water collector. It is also important to note that in the immediate vicinity of the water collector site, there is a current riverbed of the Austrian Canal that will be used and in the future.

It is anticipated that the drain of water collector is 13 hours. To make the drain of water collector in a given period, it is necessary to install a pumping station with capacity of 950 l/s. The pumping station on the Cumulative water collector consists of two pumps type DH 86-50 (after the planned revitalization) of the individual capacity of 500 l/s with a lifting height up to 20 m of water, and the necessary reserve in capacity will be provided by installation another two pumps BS 2250 with capacity of 129.5 l/s and lifting height of 25 m. Elements of the pumping station are shown in Table 2.

Economic view of investment for construction the water drainage system with the Cumulative water collector

In order for this system to function successfully, it is necessary in addition to construct the Cumulative water collector, also to construct a circumferential canal and supply the all necessary equipment for operation of this system. Of all these canals, there is currently only the Austrian canal, although it requires a small reconstruction and regulation of the riverbed. The bill of quantities that have to be realized is shown in Table 4.

Table 4 *Bill of quantities on circumferential canals*

Canals	Length [m]	General incline [‰]	Inflow level	Excavation volume [m^3]
JK-1	1,288.0	3.0	934.2	41,099.0
JK-2	523.0	15.9	937.0	17,936.0
IK-2	1,380.0	0.6	934.0	20,000.0
AK	852.0	3.2	933.5	24,857.0

Total costs of construction the drainage system with the Cumulative water collector are shown in Table 5.

Table 5 *Costs of construction the drainage facilities*

Circumferential canals			Water collector		
Canals	**Excavation volume [m³]**	**Costs of excavation [KM]**	**Part of water collector**	**Excavation volume [m³]**	**Costs of excavation [KM]**
JK-1	41,099.00	82,198	Quaternary	58,000.00	116,000
JK-2	17,936.00	35,872	Water collector	31,000.00	124,000
IK-2	20,000.00	40,000	Precipitator	5,700.00	22,800
AK	24,857.00	49,714			
Total		207,784	Total		262,800
				Total:	470,584

CONCLUSION

In order to conduct the effective and sustained mining, it is necessary to provide the required conditions for smooth operation. In the specific example, the oopen pit Gacko has complex requirements in terms of protection the open pit on water. It is necessary to pay attention to development the drainage system that will prevent the inflow of water into the open pit contour and to protect effectively the open pit alone. The efficient solution of the problem means a solution that will solve that problem, to cost a little and take a long time.

The present drainage system will completely replace the current one, and improve the protection of the open pit on water, whereby:

- to direct all collected water on the east side to the river Musnica,
- the circumferential canals will reduce the amount of water that inflows into the open pit,
- the surface water will be controlled and at a safe distance from the open pit contour,
- the main recipient will be the river Musnica whose riverbed is outside the zone of mining.

From the economic point of view, such a system is cost effective provided that a longer period would have no changes on the structures that comprise it.

From the standpoint of the efficiency, this system is intended to operate until the end-of-life of the open pit. All facilities are placed so that they can freely perform their function of drainage. It is required that the canals are regularly maintained and extended, if necessary.

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