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Estimation of damage on the equipment during the floods in opencast mines Tamnava-West field and Veliki Crljeni

Dragan Ignjatović, Predrag Jovančić, Vladimir Pavlović

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ESTIMATION OF DAMAGE ON THE EQUIPMENT DURING THE FLOODS IN OPENCAST MINES TAMNAVA-WEST FIELD AND VELIKI CRLJENI

Ignjatović D.[1], Jovančić P.[2], Pavlović V.[3]

Abstract

In May 2014, catastrophic floods hit Serbia and the majority of the Kolubara coal basin. On that occasion, the largest opencast mine in this basin, Tamnava-West Field, was completely flooded with about 190 million m^3 of water, along with all continuous systems for production.

In order to repair the active opencast mine Tamnava-West Field completely, and to return it to the designed operations, early in June, just a fortnight after the floods, the authors have assembled an expert team who elaborated a plan for the rehabilitation of these opencast mines against consequences of the flooded waters. The expert team defined *Rehabilitation Strategy,* i.e. a scheduled document covering a wide range of synchronized and manageable processes and activities on the project for implementation of rehabilitation on this opencast mine.

Strategic objectives were implemented while respecting the rules of the profession and the world's best practice in realization of similar projects, with maximum consideration of the opencast mine overall reliability, as well as measures to protect the environment and ecology in general. Established strategic objectives are mainly implemented on schedule, with minor variations in investments realization. This project on the opencast mine Tamnava-West Field reconstruction presents a good example on how to react in an emergency, like this flood. The

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rehabilitation project foresees all the necessary activities, its scope and implementation dynamics in function for the safe rehabilitation by dewatering of the flooded mine, and reliable continuation of mining. Program for the rehabilitation of flooded equipment is shown in this paper, i.e. planned work on damage estimation on mining equipment is shown, as well as comparison with results that were later received after dealing with flood consequences.

Keywords: mining mechanization, damage, rehabilitation, risks

1 Introduction

The largest producer of coal in the Mining Basin Kolubara is the opencast mine Tamnava-West Field. From the total of 30.7 million tons of coal produced in 2013, this mine has produced a record of 14.6 million of tons, which is 47% of the total production of the Kolubara basin. Along with all the produced coal, 33 million m^3 of overburden was excavated as well. Achieved production was implemented by nine continuous systems, from which eight are with bucket wheel excavators and one with a bucket chain excavator. According to the provided coal production information, opencast mine Tamnava-West Field is essential for the power generation in thermal power plant Nikola Tesla and overall energy stability in the country.

In mid-May 2014, the main parts of central and western Serbia were affected by catastrophic floods. These floods especially affected the western part of the Kolubara basin, where the opencast mine Tamnava-West Field is located. The opencast mine (OCM) was completely flooded, along with all continuous systems for production (Figure 1).

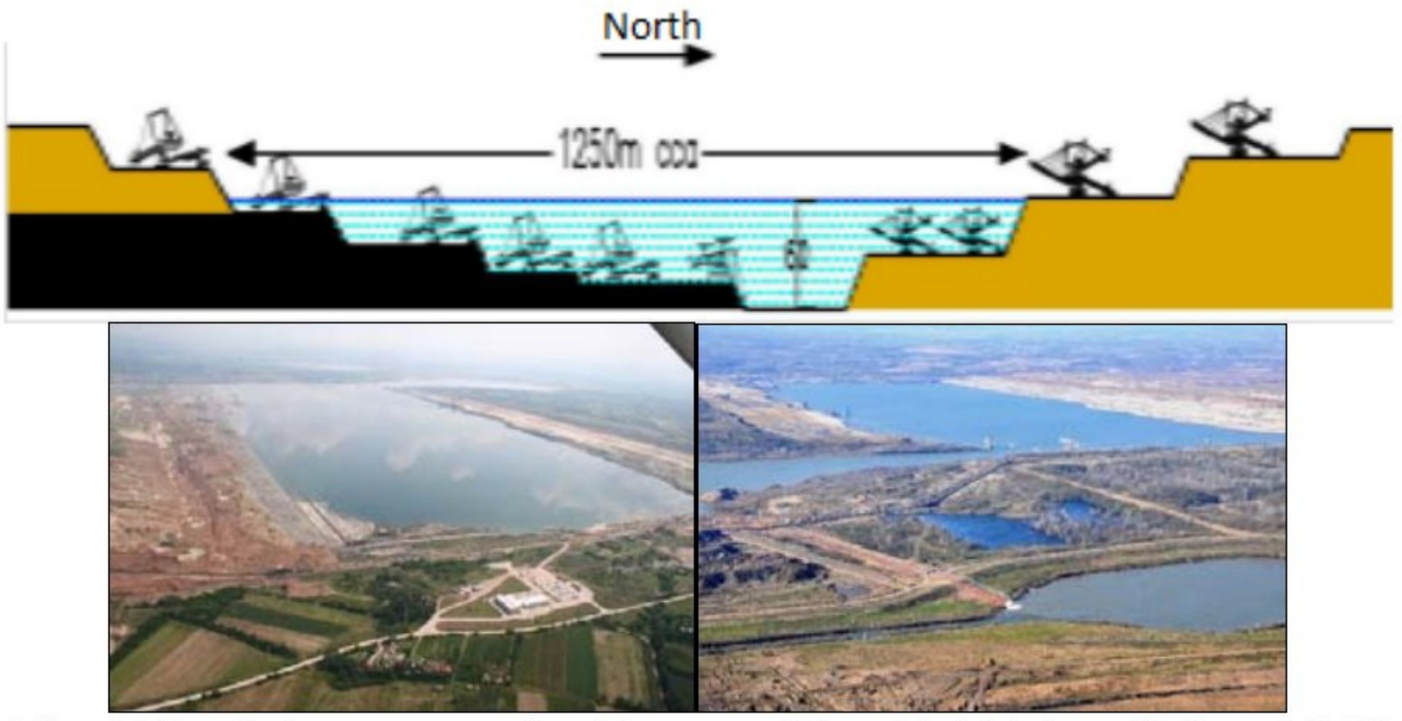


Fig. 1 Flooded opencast mine Tamnava-West Field (view: N-S and S-N)

Previous preliminary analysis show the following approximate flooded situation in the opencast mine Tamnava-West Field:

- Elevation of water table: 76.5 m
- Elevation of the deepest part of created lake: 10.2 m
- Surface of water table: 7,445,428 m^2
- Area of the opencast mine flooded part: 7,513,006 m^2
- Volume of the opencast mine flooded part: 190,586,345 m^3

Partial or complete equipment was flooded in Open pits Veliki Crljeni and Tamnava west field, only one open pit ECS system in the Tamnava west field remained untouched. Total damage of flooded equipment was: 5 bucket wheel excavators, 1 chain excavator, 6 belt wagons and spreaders, 23 drive station, 30 km of the lines, 4 draglines, and 17 pieces of auxiliary machinery (pipe layers, hydraulic excavators, dozers and cranes).

Fig. 2 Situation on the open pits Veliki Crljeni, Tamnava West field after the flood

2 After flood activities

The established expert team has developed an operational strategy as a planning document for the rehabilitation of the flooded opencast mine Tamnava-West Field. General objective of this document was to provide reliable and real dynamics for the gradual achievement of the designed production capacity in the opencast mine Tamnava-West Field. Strategic objectives of the project were, based on the analysis, to define the following:

- Optimal rehabilitation plan for the opencast mine in the function of equipment operation reliability and stability of the opencast mine;
- Dewatering dynamic of flooded opencast mine in the function of operating and final slopes stability, internal dumps and equipment and environmental protection;
- Dynamics of the opencast mine protection against surface water (river flows, retention, etc.);
- Dynamic, technology and equipment for mining on the flooded opencast mine.

3 Operational strategy for the opencast mine Tamnava-West Field rehabilitation

Project implementation of the rehabilitation strategy refers to a plan for the opencast mine rehabilitation, based on the previously conducted analysis on:

- Geometry of the flooded opencast mine, the internal dump site and location of the equipment under water;
- Stability of the opencast mine and internal dump site in the function of the flooded opencast mine dewatering dynamics;
- Stability of the opencast mine and internal dump site in the function of the mining technology and dynamics;
- Condition of river flows, retention basins and water reservoirs in the affected area on the opencast mine;
- The risk of coal mining continuation in the function of the opencast mine geometry, stability, dewatering and quality of pumped water;
- Direct and indirect damages on the opencast mine.

Since the opencast mine was completely flooded, for more reliable *situational analysis* it was necessary to perform mine, dump site and equipment geodetic underwater survey, as well as geodetic survey of river flows, retention basins and water reservoirs in the impact zone on the opencast mine, followed by an analysis of the stability of the flooded opencast mine and inside dump as well as deposit hydrodynamic model, at the end.

4 Risk assessment of project for the opencast mine Tamnava-West Field rehabilitation

Considering the importance of the opencast mine reconstruction project for the overall energy stability of the country, the high level of investments required for rehabilitation and the degree of uncertainties related to the project, the expert team has conducted an *ad-hock* risk analysis of the project.

Risk analysis covered the following aspects:

- Personnel
- Mine and equipment:
    - Pumping of water and the amount of mud in the mine
    - Degree of machinery damaged and caused by flood and funds for repair
    - Preparation for mines rehabilitation
- Environment Protection

Degree of machinery damage caused by the flood. If the flood was very strong, it could cause damage on a part of the machinery. If this happens, it could cause the following risks:

- Complete two main coal conveyor lines are destroyed;
- Undermined area on which the bucket wheel is;
- Parts of frames are destroyed;
- All the equipment of Kolubara Metal Company is destroyed.

Funds for repair. If the amount of funds for the repair is small, a complete refurbishment of flooded machinery is not to be performed, which in the future will result in less availability and higher maintenance costs:

- Funds for repair are insufficient (less than €30 million), complete replacement of the electric is not performed;
- Funds for repair are insufficient (less than €50 million), complete replacement of the electric is performed, but without mechanical parts;
- Funds for repairs are €60 million, complete replacement of the electrical is performed, and mechanical parts.

Preparation for mines rehabilitation. If the time for recovery preparation is very long, i.e. if project documentation and equipment specification for the procurement is not done on time, if the tender procedures are being done too slowly, opencast mine may be out of operation for a longer period of time:

- Project documentation is not ready, i.e. takes a long time to prepare it, consequences of the inability to compile precise specifications for procurement, possible errors in the procurement and others. *The risk is in the field 10/5 unusual but possible, and the estimated direct and indirect damage is €200 million.*
- Tender procedure has been slow, consequences are that equipment was out of operation for a long time. *Risk is in the field 10/5 unusual but possible, and the estimated direct and indirect damage amounted to €200 million.*

5 Detailed Project for rehabilitation of the opencast mine Tamnava-West Field implementation plan

Rehabilitation of the opencast mine Tamnava-West Field implementation plan is presented in Figure 3.

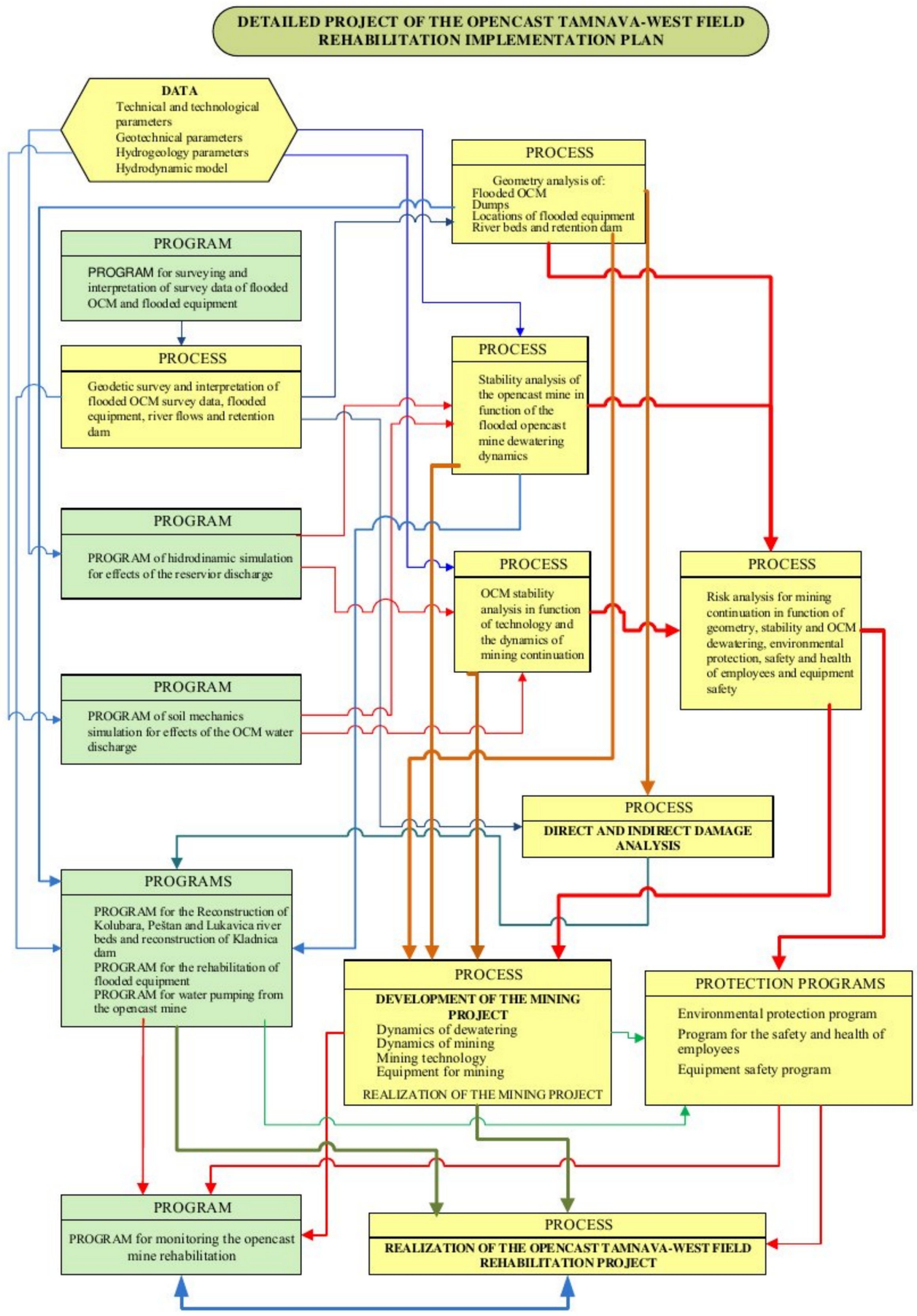


Fig. 3 The opencast mine Tamnava-West Field rehabilitation implementation plan

6 Measures and programs for the implementation of strategic objectives

To achieve the established strategic objectives, a series of hierarchically separated emergency measures were defined, with Implementation of the following programs:

- Program of surveying and development of geodetic basis
- Program of hydrodynamic simulations for effects of the reservoir discharge
- Program of soil-mechanics simulation for effects of the reservoir discharge
- Program for the reconstruction of Kolubara, Pestan and Lukavica river beds and reconstruction of Kladnica dam
- Program for water pumping from the opencast mine
- Programs for the environmental protection, safety and health of employees and equipment safety
- Program for monitoring opencast mine rehabilitation
- Program for the rehabilitation of flooded equipment

7 Program for the rehabilitation of flooded equipment

Program for the rehabilitation of flooded equipment provides defining of the investment in flooded equipment on the opencast mine with implementation time schedule. The following main and auxiliary equipment and machinery was flooded on the opencast mine: 3 overburden systems, 3 coal systems, an interburden system and 4 draglines.

8 Investment evaluation for the opencast mine rehabilitation

Defining the investment in flooded equipment in opencasts mines of the Kolubara mining basin is an extremely complex task, especially since the expert public had no previous experience in assessing the damage after such failures.

Discussions were focused on three levels of the repair works and revitalization of mining equipment according to the following criteria:

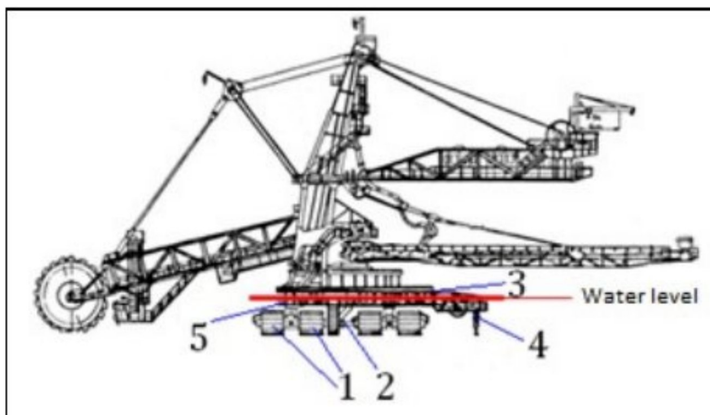
- The minimum investment and minimum time for bringing mining machinery to operating condition; these imply activities such as dismantling only basic flooded equipment, washing and cleaning, the necessary replacement of critical parts, service for all parts of mining machinery, assembly of tested and cleaned equipment, as well as functional trials (Variant 1);

- Investments that will eliminate all the negative effects of the flooded main and auxiliary mining machinery; these imply activities such as complete refurbishment/replacement of flooded segments, service for other machines parts, assembly of repaired and new equipment, as well as functional trials (Variant 2);
- Investments that include complete refurbishment and modernization of the mining machinery; these imply activities in the overall revitalization and modernization of mining equipment, with functional trials after the assembly (Variant 3).

As a clear example we will show damage assessment analysis on bucket wheel excavators SchRs 630 on the opencast mine Veliki Crljeni (G2) (Table 1), which was partially flooded and on the opencast mine Tamnava West Field (G4) (Table 2), which was completely flooded.

Since the experience with flooded equipment in Serbia was scarce, especially with the one that was more than 6 months under water, assumed required work had been defined on each excavator building group.

Main steps in order to remove all negative effects of flooded excavators G2 and G4 are shown in Figure 4 and Figure 5.



1. Reparation of elements of crawler transport and its drive;
2. Reparation of elements of the mechanism for crawler steering;
3. Reparation of *bearing* of upper carriage;
4. Sanation of VN cable winding up system;
5. Local anti-corrosion protection of steel construction of under carriage;

Fig.4 Excavator SchRs 630.25/6, internal marking G2 - activity by the Variant 1

Table 1 Comparison of prices of investment on the excavator SchRs 630.25/6 (G-2) (€)

Variant 1		**Variant 2**		**Variant 3**	
Minimal investment for bringing situation in operational condition		Investments will eliminate all the negative effects of floods		Investments in the complete revitalization and modernization	
mechanical part	electrical part	mechanical part	electrical part	mechanical part	electrical part
120.000,00	133.000,00	180.000,00	265.000,00	2.825.000,00	1.160.000,00
Total:		Total:		Total:	
253.000 €		**445.000 €**		**3.985.000 €**	
Duration of activity		Duration of activity		Duration of activity	
mechanical part	electrical part	mechanical part	electrical part	mechanical part	electrical part
30 dana	40 dana	30 dana	40 dana	90 dana	90 dana
Total		Total		Total	
40 days		**40 days**		**90 days**	

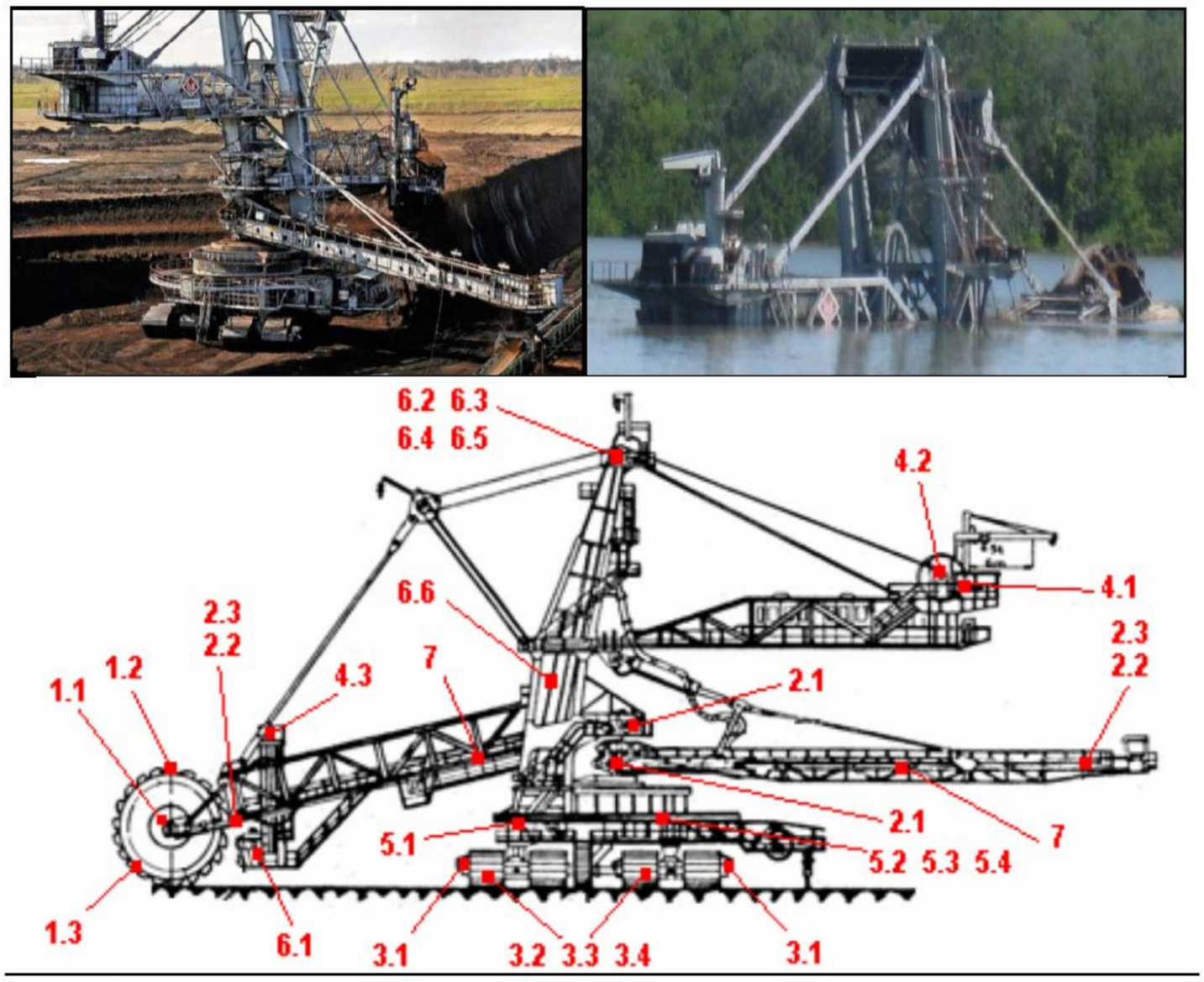


Fig. 5 Excavator SchRs 630.25/6, internal marking G4 - activity by the Variant 2

Table 2 Comparison of prices of investment on the excavator SchRs 630.25/6 (G-4) (€)

Variant 1		**Variant 2**		**Variant 3**	
Minimal investment for bringing situation in operational condition		Investments will eliminate all the negative effects of floods		Investments in the complete revitalization and modernization	
mechanical part	electrical part	mechanical part	electrical part	mechanical part	electrical part
315.000	2.046.000	949.000	2.046.000	1.949.000	2.046.000
Total		Total		Total	
2.361.000 €		**2.995.000 €**		**3.995.000 €**	
Duration of activity		Duration of activity		Duration of activity	
mechanical part	electrical part	mechanical part	electrical part	mechanical part	electrical part
40	90	40	90	40	90
Total		Total		Total	
90 days		**90 days**		**90 days**	

Variant 1 - minimal investment for bringing situation in operational condition had been acceptable option for opencast mine Veliki Crljeni. Water level was relatively low there and its activation would mitigate lack of coal in power plants. After reconstruction of coal conveyor system, open pit started its operation during August, i.e. three months after floods occurred.

Variant 2 was suitable for opencast mine Tamnava-West Field. Complete works were finished 90 days after water was pumped out and after public procurement procedure was fulfilled.

Key experiences after repairs are:

- Steel construction on excavators and spreaders did not suffer any damage. Only local anti-corrosive protection was done. There were some minor issues in winter period where water was stuck in some back pockets and when it froze.
- In the greatest part of the gear box there were no water breakthrough (especially when it comes to planetary gear boxes). Water penetration was visible in some conveyor gear boxes as well as in all dragline gearboxes (bad sealing). Damage is at minimal level.
- Partial reparation is done when it comes to drums.
- 35% of idlers were planned to be replaced and other 35% to be revitalized. Since there were some issues in public procurement procedure only 10% of idlers were replaced, but great number of failures since the operation started proves that predicted number of idlers had to be replaced and revitalized.
- Belt rubber damage was according to estimations.
- Steel ropes were fully replaced

- Part of the ballast was replaced (around 50%).
- Complete oil and grease was replaced on all machines.
- Part of hydraulics was replaced.
- Complete electro equipment was replaced as it was planned.
- Number of damaged frames was in accordance with estimation.
- In coal drive units drives with hydrodynamic coupling were replaced with frequently. regulated drives, which required partial reconstruction of bearing construction.

Unbelievable achievement was made when equipment and opencast mine were brought in functional manner for relatively brief time period (Figure 6): over 270 gear boxes of different types and sizes were rehabilitated, over 40 steel ropes of various purposes and dimensions were replaced, over 100 drums of various sizes were treated, over 7000 idlers replaced (around 10% of predicted) and 8 km of rubber, complete oil and grease in lubrication systems were replaced, complete power supply and electro equipment on flooded equipment was replaced, and modernization elements were also conducted, etc.

Fig. 6 Drive station after flood and after reconstruction

If planned works are to be compared with actual done works and its expenses, it may be concluded that predicted investments in electro equipment were € 28.57 million, and actual cost was € 28.43 million. Predicted funds for mechanical equipment were not fully spent. Reasons for that were lack of delivery of idlers and rubber for machines, swift involvement of machines in production process, but also due to problems in public procurement processes.

9 Conclusion

Flooding of the opencast mine Tamnava-West Field is a disaster caused by unprecedented floods, and as such actualizes a number of issues related to emergency response in opencast mines and mining in general. On the example of the opencast mine Tamnava-West Field, the

reconstruction project presents a good example on how to react in an emergency situation as it this flood was. Rehabilitation project foresees all the necessary activities, its scope and implementation dynamics in the function of safe rehabilitation by dewatering of the flooded mine and reliable continuation of mining.

Electric Power Industry of Serbia, and especially employees of the Mining Basin Kolubara, put in serious efforts so that the process of flood rehabilitation is done in a coordinated and more efficient manner, on the basis of the presented and accepted Operational Strategy.

The plan anticipated that the complete electrical equipment is to be replaced by new one, which has been done. Estimated value of damaged electric equipment was €28.57 million, and the actual costs amounted to €28.43 million. Spent funds for mechanical equipment were not fully spent due to lack of delivery of idlers and rubber for machines, swift involvement of machines in production process, but also due to problems in public procurement processes.

When mechanical equipment is in question, Option 2 was applied on opencast mine Tamnava West Field, and Type 1 on opencast mine Veliki Crljeni. Established strategic objectives are mainly implemented on schedule, with minor variations in the realization of investments and mud extraction, with respecting the rules of the profession and the world's best practice in the implementation of similar projects and maximum consideration of overall operating reliability of opencast mines as well as measures to protect the environment and ecology in general.

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