TECHNICAL SOLUTION FOR RECULTIVATION OF LIMESTONE OPENCAST MINE AND DUMP SPASINE – BRDJANI NEAR UGLJEVIK

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ABSTRACT
There will be a change in the terrain due to limestone mining at the opencast mine Spasine-Brdjani near Ugljevik. It should be brought to a state which will fit into the environment ecologically, with recultivation measures. This technical solution was an attempt to bring this terrain to a condition that does not deviate from the environment, but which can also be used for agricultural purposes after the end of mining, thanks to measures of technical and biological reclamation with minimal economic costs.
Keywords: *recultivation, opencast mine, dump, Spasine-Brdjani*

INTRODUCTION

The Spasine-Brdjani limestone deposit belongs to the municipality of Ugljevik (Republika Srpska), which is economically well developed. In addition to agriculture (fruit and livestock), mining (coal) and related industries have also been developed. Ugljevik is located on the banks of the Janja River, at twenty kilometers distance from Bijeljina going towards Tuzla. The distance of Ugljevik from Brcko is about 30 km, while it is about 53 km distance from Zvornik, and about 48 km from Tuzla.

After the end of limestone mining at the opencast mine Spasine-Brdjani, in addition to the excavation itself, there will be an external overburden dump. Those are also the areas intended for reclamation. During the final contour of the opencast mine, flat surfaces and slopes are planned for reclamation. Same goes for the outside dump. Figure 1 shows the flat (yellow) and oblique (green) surfaces in the final contour of the opencast limestone mine Spasine-Brdjani, as well as the flat and oblique surfaces on the outside dump intended for reclamation. Tables 1 and 2 show the surfaces of the horizontal and oblique areas.

Table 1. Flat surface areas

Bench	Label	Flat surfaces	
		(m^2)	(ha)
E 310	1r	664	0.066
E 310	2r	2424	0.242
E 300	3r	6888	0.688
E 290	4r	11008	1.100
E 280	5r	94837	9.483
E 302 - dump	6r	72808	7.280
Total		**188629**	**18.863**

The climate in the area of Ugljevik, and thus in the wider area of the Spasine-Brdjani deposit, has all the characteristics of a moderate continental climate with cold winters and warm summers. In-between are the transitional seasons, fresher autumns and wetter springs.

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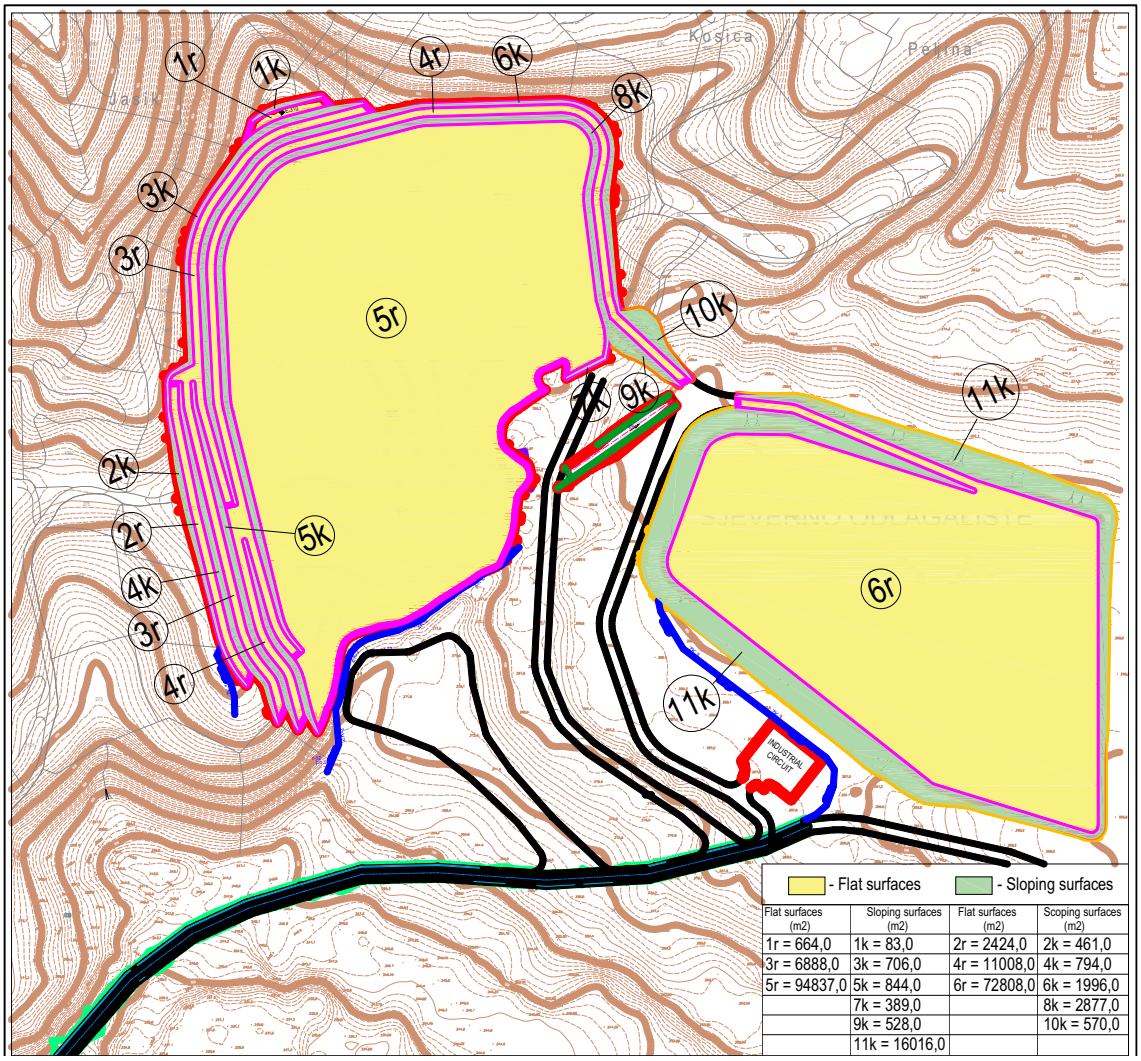

Figure 1. Surfaces for recultivation

Table 2. Sloping dump surface areas

Bench	Label	Oblique surfaces	
		(m²)	(ha)
Do 300	1k	528	0.0528
Do 300	2k	570	0.0572
Do 302	3k	16016	1.601
Total		**17110**	**1.711**

The Spasine-Brdjani deposit mostly consists of Badenian chalk and limestone, as well as Sarmatian limestone and quaternary formations (eluvial-deluvial sediments of insignificant thickness).

Recultivation has two phases; technical and biological recultivation. Technical recultivation shapes the mine in order to fit in with the landscape and create optimal conditions for biological recultivation. Technical recultivation is done by the mining equipment and operatives, while the biological part is done by a specialized company for landscape architecture, agriculture and forestry.

TECHNICAL RECULTIVATION

Considering the properties of the substrate, the precipitation regime and the chosen direction of recultivation, the dump is formed so that the general slope of the plane is 0.5%. A counter slope of 1 to 2% should be provided on the bench levels of the mine.

Technical recultivation implies preparation of the terrain for biological recultivation and includes the following number of measures and procedures: leveling and shaping of surfaces on the dump and mine benches, shaping the mine and dump slopes, fine leveling (planning) of mine and dump surfaces, construction of canals and access roads.

Road construction - Access roads on the mine and dump are used for the delivery of humus or soil and the transport of seedlings, equipment and personnel. The first course of action is creating new access roads with a bulldozer or leveling existing access roads. These earth roads are constructed in a width that enables the movement of the largest mechanization that will be engaged in technical and biological recultivation, as well as in the later phase of using that space.

Earth roads on dumps are made with a bulldozer and grader from the local earth material without the addition of binders. The planum of these earth roads is the deposited overburden. Earth roads are filled only in places where there is unevenness, or material with less resistance to pressure. By the end of the technical reclamation works, 2,388 m of dirt roads will be made at the mine, and 1,685 m of dirt roads at the dump (Figure 2).

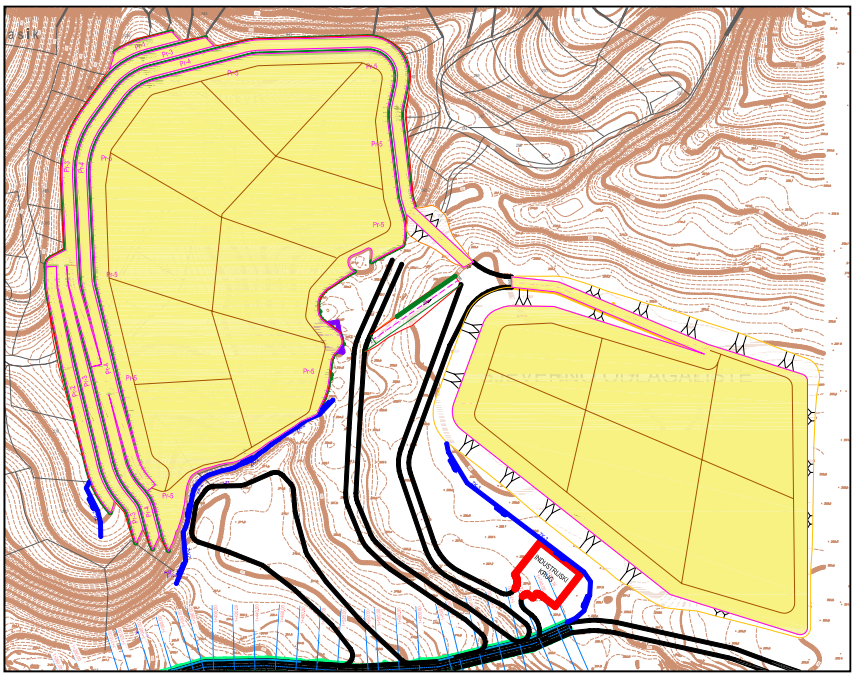

Figure 2. Areas meant for technical recultivation and dirt roads

Planning of horizontal surfaces - A bulldozer of the CAT D9R type, a loader with a 4 m^3 bucket volume and trucks with a 17.5 m^3 volume and a 26 t payload capacity will be hired to perform works on the dump surfaces planning. It is the equipment which will remain after the limestone mining.

Technical recultivation works are done in the following order: planning, and in cases when it is necessary to transport the soil at distances greater than 100 m also loading, transport and dumping.

Just planning will be done on the horizontal surfaces of the final benches and berms of the mine and dump. The material used for surface planning comes from the dump itself. The slopes of the existing dump surfaces should be inclined towards the access roads and canals by bulking material on both sides of the road with a slope of up to 3 ‰.

That way the erosion effects of the water that falls directly on the surfaces of mine and dump are reduced. Planning of mine and dump benches will be done with a CAT D9R type bulldozer or bulldozers with similar technical characteristics. The total horizontal areas planned for bulldozer planning are 188,629 m^2 and are shown as yellow in Figure 2.

The mean thickness of cutting material during planning is 0.3 m and was determined as a weighted average thickness of the cut on the vertical sections of horizontal surfaces. Based on that, the total mass on the horizontal surfaces planning is 56,589 m^3. The capacity of the bulldozer on the planning of the horizontal surfaces of the dump was calculated for the average transport length of 50 m. As the capacity of the bulldozer is 298 m^3/h, the effective working time of the bulldozer will be 190 h for the 56,589 m^3 amount of material.

Covering horizontal surfaces of mine and dump with humus – Before starting limestone mining, a 0.15 m thick layer of humus will be excavated, which totals 17,373 m^3. In order to cover all horizontal surfaces with a humus layer after mining, it is necessary to procure another 20,353 m^3 of humus, which will be delivered to the opencast mine at the predetermined location. Spreading humus on horizontal surfaces is planned in a 0.2 m layer. Humus spreading works during technical reclamation have the following order: loading, transport and planning.

Since the soil's physical and mechanical characteristics enable direct excavation, the ULT-220 loader with a 3 m^3 bucket volume will be used for the preparation (excavation) of humus. The material transport for surface reclamation will be done by trucks with a payload capacity of 26 t, which are available at the mine. Planning of horizontal surfaces with humus is done with a CAT D9R type bulldozer.

The hourly production of the ULT 220 type loader on loading these masses is 174 m^3/h. The required time for hiring one loader to load humus is 217 h. The humus will be transported from the place intended for disposal to the destination on the final levels of the mine and dump. The hourly production capacity of the truck is 63 m^3/h. The effective operating truck time for 37,726 m^3 quantities of humus for an average transport of 1 km is 600 h. Therefore 3 trucks are needed for the work of one loader.

Humus planning on horizontal surfaces of the outside and inside dump will be done mostly by CAT D9R type bulldozer or bulldozers with similar technical characteristics. The production of the humus planning bulldozer was calculated for an average transport length of 50 m and amounts to 306.4 m^3/h. The production of the CAT D9R bulldozer is reduced by 20% in relation to the calculated production, taking into account the characteristics of the material (stickiness) and the specificity of this type of bulldozer operation (multi-pass planning), so that the technical production of the bulldozer is 245 m^3/h. According to the total amount of material (37,726 m^3) that will be planned by the bulldozer on the inside dump, the time for which the bulldozer will perform this type of work is 154 h.

Working on bench planes and slopes - The technology of final surface and berm formation on the final mine slopes implies fine surface planning and berm cutting, which is done with a slope towards the toe of the upper bench. Berm cutting on the slopes is performed by lowering the bulldozer plow and burying it in the ground at an inclination of 3-5‰ in relation to the horizontal plane and separating a cut with a 0.2 to 0.8 m thickness. The separated material gathers in front of the plow, forming a traction prism with a width smaller than the width of the bulldozer plow. As the bulldozer plow is slanted, the material is thrown sideways from the plow and deposited down the dump slope. The berms are cut in all the places where the berm falls towards the crest of the lower bench.

The total area of berms on the mine for cutting and planning is 20,984 m^2. The average thickness of the planned masses is 0.5 m and was determined on a number of characteristic profiles. Based on this, the total mass that needs to be planned by cutting berms is 10,492 m^3. The 471.1 m^3/h bulldozer production was calculated when working on levelling with a slope of 0.5% with an average material transport length of 30 m. The actual CAT D9R bulldozer production is reduced by 30% in relation to the calculated production taking into account the characteristics of the material (stickiness) and the specificity of this type of bulldozer operation (multi-pass planning), so the technical capacity of the bulldozer is 329 m^3/h. According to the total amount of material that will be cut and planned, the time for which the bulldozer will perform this type of work is 32 hours.

The following manpower is required to perform the technical reclamation works: one leading engineer who will perform the supervision, one bulldozer and loader operator, three truck drivers and two auxiliary workers. The time required to perform the planned works on technical reclamation is 72 hours (3 days).

BIOLOGICAL RECULTIVATION

Since it's an opencast limestone mine, an absence of organic matter, low content of plant nutrients and poor water-physical properties are to be expected. These are the basic limitating factors that need to be removed for the successful emergence and development of plants.

Selection of recultivation plants - When selecting plants for recultivation, in addition to natural conditions, it is necessary to consider the population structure, total income and participation of individual industries in it, structure of land and potential users of reclaimed areas.

Among natural conditions - climate, relief and edaphone are of decisive importance for the choice of plants for recultivation. Since the climatic conditions are favorable for the plants that grow in this climate, more attention should be paid to the conditions of the terrain and the substrate itself.

The dump planum should be shaped to have a slight inclination (about 0.5%), in order to allow precipitation to be retained for irrigation but not to have excess surface water, because that would cause root asphyxia by squeezing oxygen from the root zone.

When choosing the direction of biological recultivation, it's important make the area compatible for all possible end users. These are the chosen directions of recultivation: establishment of clover-grass mixture as the basic, initial direction of recultivation and partial forest recultivation as a supplementary direction of reclamation.

The components of the clover-grass mixture will humify the substrate and enrich it with nutrients through its own secretions and underground and above-ground parts. Thus, it will create conditions for other, economically more useful crops, which have higher requirements in relation to the physical and chemical properties of the soil. This mixture has a great protective effect against leaching. Legumes have a deeper root system, so they will bind the substrate particles deeper. Graminas have a shallow root system, but very fibrous, which strongly permeates the substrate particles on the surface, fixes them and thus prevents leaching.

Clover-grass mixtures are suitable for quick reorientation to other types of recultivation, i.e. to cultivation of forest, fruit and intensive field crops. Also, this type of fast recultivation is one of the cheapest ways of biological reclamation. For these reasons, the entire surface of the mine, dump and even berms will be covered by a clover-grass mixture.

The species given in Table 3 are part of the clover grass mixture.

Table 3. Clover-grass mixture

	Species	% Representation in the mixture	Sowing rates in kg/ha		
			Pure species	Species in the mix	Return quantity 2*
	Clover	**70**		19,5	39
1.	Alfalfa (*medicago sativa*)	40	30	12	24
2.	Bird's-foot trefoil (*latus cerniculatus*)	15	20	3	6
3.	Melilotus (*meliotus ap*)	15	30	4,5	9
	Grass	**30**		15	30
4.	Cat grass (*dactylis glomerata*)	10	40	4	8
5.	Red Fescue (*festuca rubra*)	10	40	4	8
6.	Tall oatgrass (*avena elatoir*)	10	70	7	14
	Total	**100**			**69**

These components tolerate drought relatively well and have a slightly wider range of requirements for the substrate. Frost resistance is satisfactory. The ratio of legumes and grasses is 70:30, which corresponds to the ratio reached by research in other countries.

Forest recultivation will be carried out on the formed dump slope. Partial afforestation of the mine bench areas will contribute to its stabilization to a certain extent, so this type of afforestation should be understood primarily as a bioengineering measure.

The species for partial forest reclamation will be black locust. Black locust seems to be the best option because: it propagates quickly, has a high growth rate in the first period of its life, binds the soil well with the roots so it is favorable for its stabilization, seedlings are relatively cheap so it's agreeable for high planting density. Also, it has an extremely long flowering period (successively almost during the entire vegetation), so it is favorable for beekeeping.

Biological recultivation technology – The grass cover in this case will have a protective role because it prevents aeolian erosion - raising dust by wind. It is known that certain plant species can contribute to the stability of different soils by rapid development of the root system and aboveground vegetative mass.

The success of growing plants depends on the applied category of recultivation above all. Clover grass mixtures with components as given in Table 3 should be sown in spring on flat surfaces.

Black locust afforestation is required on the dump sloping surfaces and partly on the opencast mine benches. Pits for seedlings have a diameter of 0.4 m and a depth of 0.4 m. Planting in the pit is done according to a triangular scheme with a planting distance of 2.23*2.23 m, which corresponds to the number of 2,000 seedlings per hectare. The longitudinal section of planting black locust seedlings on sloping and flat surfaces is shown in Figure 3. Black locust seedlings for afforestation must be first class with a free, well-formed and developed root system.

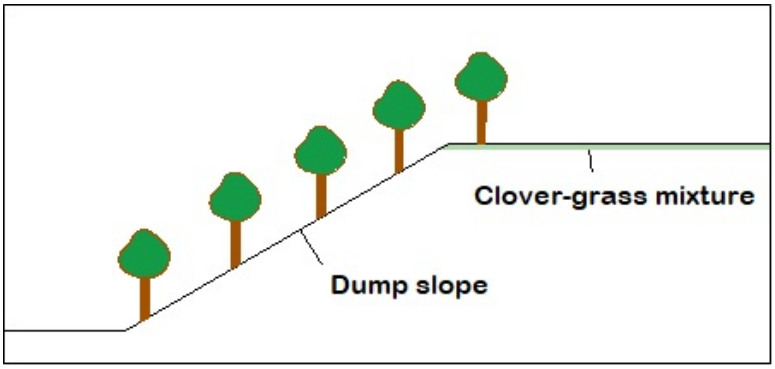

Figure 3. Longitudinal section of planting black locust seedlings on the sloping dump surface

Black locust (lat. *Robinia pseudoacacia*) is a species that is very adaptable to shallow and dry habitats. It propagates well, successfully withstands drought, frost, wind and at the same time repairs the soil. Black locust thrives on substrates with extreme bearing conditions. It is a woody perennial plant belonging to the genus of deciduous trees. The black locust tree grows up to 25 m in height. It blooms in May, and the white fragrant flowers grow in clusters and secrete a lot of nectar. Bees visit flowers, collect pollen and make honey. In addition to honey, royal jelly, propolis and beeswax are obtained. The fruit of black locust is a flat legume up to 11 cm long, with 4 to 10 kidney-shaped seeds. Fresh legume and seeds contain a lot of proteins, carbohydrates and fats. Legumes can be canned by drying and used as vegetables. Dried black locust leaf is used as food for small domestic animals (sheep, goats) in the winter. Black locust wood is used as building material, for the production of roof structures and pillars for espalier, in the erection of orchards, for raspberries and blackberries. Black locust is also a high-quality firewood.

The most favorable period for planting black locust is autumn. The advantages of autumn seedlings planting over spring are reflected in the fact that in autumn there is a longer period for propagating because there is more moisture in the soil. The seedlings are protected by a snow cover from low temperatures and frost during the winter. After the snow melts in the spring, the planted seedlings continue to develop normally.

A warm and dry period soon occurs after the snow melts, so the plants planted in spring do not have enough moisture to develop. Thus, the lack of sufficient moisture in the substrate for the propagation and development of seedlings is the first in a series of factors that limit the success of spring seedlings planting.

The required number of black locust seedlings for afforestation of the sloping dump surface is 3,523, taking the expected losses of 10% into account. The required number of black locust seedlings for afforestation of mine benches is 965. The required number of seedlings for flat mine surface (with 10%) is 629 seedlings, while the flat dump surface requires (with 10%) 627 black locust seedlings.

The spring period should be used for sowing clover-grass mixtures. Additional sowing in the area where for some reason no grass has sprouted should be done a month after the first sowing. For example, if sowing was done in April, additional sowing should be done in May and those areas should be sprayed.

When planting seedlings, the excavated pits are first filled at the bottom with up to 1/3 of the pit height. The seedling is placed vertically in the pit so that the root veins take as natural a position as possible along the entire depth. The root of the plant is filled with soil mixed with 2 kg of burnt manure so that the root neck is 1 to 2 cm below ground level. After planting, tread the immediate surroundings of the seedling well in order to eliminate the danger of air pockets formation along the root of the seedling, because that would cause root veins drying, followed by the seedlings.

After planting black locust in spring, it is obligatory to shorten the above-ground part to 0.2 m from the ground surface in order to achieve a balance between the underground and above-ground part of the plant. Seedlings are fertilized with manure or peat in the amount of 2 kg per seedling, and mineral fertilizers NPK (0.1 kg per seedling) and KAN (0.1 kg per seedling) which is added to the substrate during planting.

The required amount of clover-grass mixture seeds with taking additional sowing into account is 1,414 kg. Grassing of flat surfaces on the final level of the dump aims to create green grass surfaces in order to protect against aeolian erosion. Grassing works include: machine sowing of grass mixtures (sowing depth ranges between 1-1.5 cm), rolling sown areas (in one roller pass with sowing), starting fertilization with NPK (15:15:15) fertilizer of 500 kg/ha for clover-grass mixture and additional mineral nitrogen fertilizer KAN or UREA of 200 kg/ha, sprinkling (watering) sown areas until grass emergence and afterwards - depending on meteorological conditions.

Conditions for the formation of humus will be created by mowing clover-grass mixtures and spreading hay on flat surfaces. By repeating this procedure (mowing and spreading hay) in the next few years, the areas might become usable for growing grain, corn and other agricultural crops. After a period of 3 years, the clover-grass mixture can also be used as animal feed.

No other way of reusing overburden is planned with this type of landscaping apart from the optimal nutrition of plants with the use of mineral fertilizers, therefore it will not require major material investments. The success of plant development will depend on natural conditions during and after sowing (winds and precipitation), as well as on the quality of sowing and necessary watering immediately after sowing until the full emergence of crops in the absence of rainy days at that time - for which there is a high probability (watering of sown areas whenever necessary).

The appearance of the Spasina limestone opencast mine and dump at the end of the biological phase of recultivation is shown in Figure 4. Light green colors represent flat surfaces with grass-legume mixture, while dark green color represents the sloping areas with black locust.

Irrigation of recultivated areas - Hydrographic conditions, especially those that will be formed after mining, have no impact on future dry agricultural production. When growing agricultural and even partially forest crops, a positive impact of groundwater is not reliable. Only atmospheric water that falls directly on the recultivated areas can be counted on.

In addition to previous recultivation measures in order to revitalize the substrate, due to obviously unfavorable properties for successful plant development, especially in the germination phase and the first stages of development, there is a need to provide the necessary amounts of water for watering crops. The necessary amount of water for irrigation will be provided by cisterns. The use of water for spraying is necessary because of the possible removal of the substrate and sown seeds by wind, especially until the plants take root.

Watering (wetting the dump surface) aims to keep the surface layer moist. About 2 l/m^2 per day is needed for watering the recultivated areas.

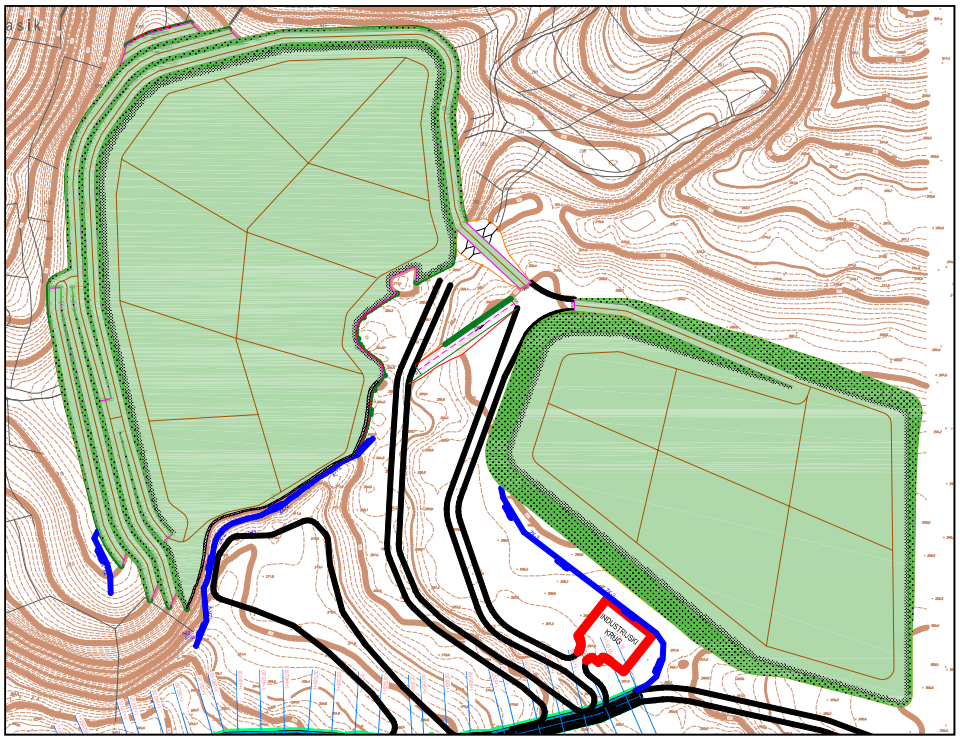

Figure 4. Surfaces after biological recultivation

CONCLUSION

After the anticipated 30 years mining period, there will be certain changes in the terrain, i.e. the excavated part will remain and an outside dump will be formed. It is necessary to recultivate 18,863 ha of horizontal and 1,711 ha of sloping areas.

Technical recultivation will be used for leveling and shaping the surfaces opencast mine and dump benches, shaping the mine and dump slopes, fine planning of the mine and dump surfaces, as well as the construction of access roads. Works on technical reclamation will last 72 days and will cost € 128,000.

After the completion of technical recultivation, work on biological recultivation will begin with sowing a clover-grass mixture on flat surfaces and planting black locust seedlings on sloping surfaces. The total costs of performing works on biological reclamation amount to € 67,000.

The total costs of technical and biological reclamation amount to € 195,000 or € 9,478 per ha. Seeing as limestone opencast mine Spasine-Brdjani is supposed to last 30 years, the annual amount that should be singled out for recultivation is 6,500 €, which is not a big expense.

REFERENCES

[1] Institute d.o.o. Tuzla and Opencast Mining Centre d.o.o. Belgrade (2020), Main mining project of carbonate raw material mining on the opencast mine Spasine-Brdjani near Ugljevik, Tuzla