Methodology for assessing the opportunity of flooding of former open-pits in the context of land reclamation

Apostu Izabela – Maria, Lazar Maria

Department of Environmental Engineering and Geology, Faculty of Mining, University of Petrosani, Petrosani, Romania

Correspondence

Apostu Izabela – Maria, Department on Environmental Engineering and Geology, Faculty of Mining, University of Petrosani, Petrosani, Romania
Email: izabelamaria.nyari@yahoo.com

Abstract

As a result of open-pit mining exploitations, impressive size gaps occur in the landscape. Their flooding leads to the occurrence of so-called open-pit lakes and represents an interesting way to reclaim the degraded land. Because there is still no way to evaluate the opportunity of flooding the open pits, a methodology for assessing this opportunity was developed in order to identify the open-pits that are suitable for flooding. For this purpose, more criteria have been established that allow a complex assessment of the flooding opportunity. The methodology also aims to ensure maximum safety conditions in the former mining perimeter, the socio-economic and cultural requirements of local communities and the harmonization of the land in accordance with adjacent ecosystems.

KEYWORDS

open-pit, flooding, opportunity assessment, evaluation matrix, reclamation

1 INTRODUCTION

The process of planning, recovery and reuse of open-pit degraded lands, which ensures the sustainable development of a former mining region, must take into account environmental aspects and the socio-cultural requirements of the population. The correct rehabilitation of the former open-pits and, in general, of the former mining areas, must tend towards a clear objective: naturalistic area, recreational area, industrial area etc. Multiple land reuse is a relatively new practice that involves combining different forms of use, which complement each other. (Lazar, 2017)

Former open-pits can be recovered and reused for various purposes, such as: landfills, off-road circuits, amphitheaters, quarry lakes that can take over various functions etc., but based on a well-defined methodology and representative criteria can be chosen the most suitable reuse option.

Open-pit lakes are simple bodies of water, formed through natural flooding (inflow of water from precipitation or aquifers) and/or artificial flooding (water adductions from water sources located in the adjacent areas) of the gaps resulting after the cessation of the open-pit exploitation activity.

When there is a possibility to flood them after the cessation of the mining works, giving rise to the so-called open-pit lakes, several possibilities of reuse occur. The most common uses of the open-pit lakes are: lakes for recreation, lakes for fish farming, natural lakes, potable or industrial water reservoir, irrigation water tank, retention basin for protection against floods etc. Regardless of the type of reuse, the open-pit lakes offer a number of benefits from an ecological and economic point of view.

2 MATERIALS AND METHODS

Starting from a good knowledge of the flooding process, have been identified the criteria that influence this process. These criteria were described and analyzed in detail, because based on them was developed the matrix for assessing the flooding opportunity of the remaining gaps. Thus, in the following is presented an original methodology for establishing the extent to which the flooding of the remaining gaps of lignite open-pits is an opportune measure for the rehabilitation of degraded lands.

2.1 Assessing criteria

Taking into account the characteristics and aspects that allow the separation and even elimination of the pits that are not suitable for flooding, the following assessing criteria have been established (Figure 1) for assessing the opportunity of flooding of open-pits:

For abandoned open-pits that have been partially reintegrated into the landscape naturally, it is only possible to carry out maintenance and support works for the acceleration and harmonious reintegration of the degraded land into the landscape.

2.1.1 Criterion C1 - Geomorphology and orography of the area

The studies regarding the geomorphological and orographic conditions provides informations on the characteristics of the site, such as relief forms, altitude, inclination, their way of grouping and spreading in the territory in which the useful mineral substances deposit was formed. Depending on the site-specific relief forms, the exploitable deposit may be concentrated: *in the hilly area* (Figure 2a,b)*, in the hilly and meadow area* (Figure 2c) or *in the meadow area* (Figure 2d), so it is possible to make an assessment regarding the possibility of occurrence of a remaining gap in the mining perimeter taking into account, in particular, the development of the useful mineral substances deposit and the characteristic forms of

relief. (Apostu & Lazar, Possibilities of flooding of the remaining gaps of the quarries from the Rovinari Mining Basin, 2018)

2.1.2 Criterion C2 - Configuration of the remaining gap

The excavation, transportation and dumping technologies applied in the open-pit mining perimeters determine the configuration of the remaining gap, respectively the final shape and geometric elements of the final slopes. Depending on the site's relief forms, the position of the deposit relative to the surrounding land, the volume of the inner dump related to the volume of the remaining gap there are 4 situations (Figure 3a,d). The depth can be measured relative to the level of the surrounding land or to the upper platform of the inner dump if this exceed the level of the surrounding land (Figure 4). (Apostu & Lazar, Possibilities of flooding of the remaining gaps of the quarries from the Rovinari Mining Basin, 2018)

It is important to know the configuration of the remaining gap, to determine the floodable volume of the open-pit and the required amount of water.

2.1.3 Criterion C3 - Necessity to restore the aquifer resources

In many cases, the open-pit exploitation of useful mineral substances can be achieved only under the conditions of natural drainage (through quarry slopes) or artificial drainage (through dewatering drillings) of aquifer formations in the mining perimeter.

The effect of dewatering works is manifested by a quantitative impact on phreatic or deep aquifers, these works leading to the expansion of depression curves and the decrease or even disappearance of groundwater resources, with direct negative effects: the drying of the wells, reduction of water intake flows, damage to vegetation etc. (Huidu, 2012)

If the natural restoration of aquifers isn't possible, the water requirements of each type of land use shall be taken into account for the assessment of the necessity to restore groundwater resources which largely depends on the type of use of adjacent land/lands.

In order to prevent and reduce the negative effects of drought, programs should be drawn up which include measures to give priority to the supply of potable water and to the irrigation of crops. (Lazăr M. , 2001)

Depending on the type of use and water requirements, the lands were classified into 9 categories, ranked and evaluated by grading them with grades (x) from 1 to 9. It is also important to know the priorities in terms of potable water supply. Thus, a hierarchy of priorities was established according to the type of land use and the values of a priority coefficient (c) were defined from 1 to 4 (Figure 5).

Thus, grade 1 is given to land occupied by transport, communications and utilities as it does not involve water consumption (in their exploitation period) and grade 9 is given to agricultural land that has the highest requirements for the water. The highest value for the priority coefficient belongs to the land/type of use which, in case of drought, depends on the potable water supply, so it has priority.

For the evaluation of adjacent lands with multiple uses, the weighted average (Equation 1) will be calculated, taking into account the value of the land (grade, x) and the priority coefficients (c), depending on the water requirements of the land, respectively the potable water supply priority.

$$M_p = \frac{\sum x_i \cdot c_i}{\sum c_i} \quad (1)$$

The weighted average ensures a proper assessment of the necessity to restore aquifer resources. Thus, given that a land has multiple uses, the weighted average allows obtaining a value favorable to the type of use with higher requirements for water in general, respectively for potable water.

2.1.4 Criterion C4 - Necessity of appearance of a water body in the area

The flooding method of former open-pits involves the appearance in the area of a water body, respectively a new aquatic ecosystem whose structure depends on the type of future use, in a territory that previously did not meet such conditions.

Taking into account the specific of the area and the development strategy of the region, the occurence of a water body can have a major significance. For example, in an agricultural area, such a lake can be used as a water reservoir for irrigating crops during dry periods. If the regional development strategy aims at tourism development, the lake can be arranged in order to carry out recreational and leisure activities, a use that can also ensure the economic development of the region. On the other hand, the lake can be populated with fish in order to support sustainable fishing (fish farming) or to practice recreational sport fishing. If the area of activity specific to a region is hunting, the creation of a water body is not strictly necessary, but the occurence of a lake in the landscape does not affect the way this activity is carried out. (Nyari, Lazăr, & Faur, 2017)

The necessity for occurence of a water body in a given region can be assessed in terms of the characteristic areas of activity in the immediate vicinity of the mining perimeter and the water requirements specific to each area (Figure 6).

2.1.5 Criterion C5 – Hydrology and hydrogeology of the region

The presence of permanent water sources, such as rainwater, aquifers and, less frequently, surface watercourses (streams, rivers etc.), are considered of major importance when applying the flooding method, as it ensures the flooding of the open-pit naturally and in a shorter period of time. Natural flooding involves lower costs, no water supply being required.

The supply of an open-pit lake is generally achieved by water supply from underground infiltrations and precipitation, and the discharge of water from the lake

is achieved by natural drainage and evaporation process. In this way, a balance is ensured between the supply and the water losses of the newly formed lake.

Depending on the geographical location, respectively the specific climatic conditions given by the amount of precipitation water (Q_P; $Q_P \geq 0$) that reaches the lake and the amount of water evaporated from the surface of the lake (Q_E; $Q_E > 0$), the amount of water that actually contributes to the flooding of the open-pit can be determined. Depending on the ratio between the amount of precipitation and the amount of evaporated water, there are several situations (Figure 7). (Apostu & Lazar, 2018)

The presence of aquifer resources is essential for the formation of an open-pit lake, naturally, as in most cases the inflow of water from rainfall is insufficient. If the influx of groundwater can significantly contribute to the flooding of the gap, then the creation of an open-pit lake is an opportune choice. Otherwise, it is recommended to choose another type of reuse.

Over time, numerous studies have been conducted to assess the degree of difficulty of exploitation of the deposits depending on the hydrogeological conditions specific to the region. According to a complex classification existing in the literature, exploitable deposits can be classified hydrogeologically into four classes. (Rotunjanu & Lazăr, 2014)

Although in the exploitation stage, the large water inflows are not desirable, because they makes difficult the exploitation and dewatering works, involve high financial costs and risks regarding the safety of employees and equipment, in the recovery and reintegration into the landscape stage, by creating a lake, these hydrogeological characteristics are favorable, as they ensure the restoration of aquifer resources and the flooding of the gap naturally in a relatively short period of time, without additional costs. In this sense, an analogy was made between the degree of difficulty of the exploitation of the deposits depending on the characteristic hydrogeological conditions and the possibilities of flooding the former open-pits. Therefore, the more difficult the hydrogeological conditions during the exploitation and the higher the groundwater inflows, the higher are the possibilities of flooding the open-pit after the cessation of the exploitation activity.

In addition, it is possible to evaluate the storage and release capacity of water by rocks, the possibility of flooding and maintaining a constant level of water in the lake, the speed of water discharge from the lake through an important physical characteristic, namely permeability of rocks. Non-cohesive rocks with large granulation drain more easily (sand, gravel), while pseudo-cohesive rocks with fine granulation (dust, clay) release water very hard. (Rotunjanu & Lazăr, 2014)

2.1.6 Criterion C6 - Stability conditions of the final slopes

In general, the former open-pits are bordered by the final in-situ and inner dump slopes. Decommissioning the dewatering systems, restoring the aquifer resources and raising the water level in the lake, influences the stability of the slopes negatively, by manifesting the pore water pressure and/or the hydrodynamic pressure under the conditions of formation of aquifers currents, but also positively by the water pressure manifested on the slopes surface. Knowing the behavior of rocks in contact with water and the geotechnical risks that may occur in the newly created

conditions is essential for increasing the security and safety of objectives and people in areas of influence. (Nyari, Lazăr, & Faur, 2017)

It is important to assess the stability of the final slopes before the flooding and to identify all the influencing factors (the influence of water, overloads, seismic shocks etc.) in order to be able to estimate the stability reserve trend, over time.

Through the excavation, transport and dumping processes, the strength characteristics of the rocks suffer important changes, so the dump slopes are characterized by lower stability reserves compared to in-situ slopes. When assessing the opportunity of flooding an open-pit according to the stability conditions of the final slopes, the unfavorable situations are taken into account.

The optimal value of the safety factor for earthworks with a long residence time is recommended to be between 1.25 ÷ 1.5. Depending on the degree of stability, waste rock deposits (dumps) were classified into four categories. (Rotunjanu, 2005)

2.1.7 Criterion C7 - Accessibility and distance to the areas of interest

In the stage of recovery and reconstruction of degraded lands, the existence of permanent roads and short access roads to the objectives of interest (such as utilities, cities etc.) is an advantage, primarily in terms of financial. If the type of reuse requires the frequent presence of staff and/or visitors, it is necessary to connect to existing transport routes and build an appropriate infrastructure.

In most countries, road networks reflect the development of a hierarchy of roads, with highways at the highest level and local access roads at the lowest. The structure of road (unpaved, paved, with semi-permanent pavements and with permanent pavements) is established depending on the distance between the objectives, on the traffic regime (open or closed to public traffic) and traffic intensity (very intens to reduced traffic intensity). (***, 2020)

If the identified roads are of the same rank and have the same condition, the differentiation of the score can be done according to other aspects, such as: the length of the roads that make the connection between the open-pit and a main road.

It is important to assess the possibility of reusing an open-pit taking into account the distance from the areas of interest (cities, agricultural areas etc.), as the advantages are greater the shorter is this distance.

Naturalistic recovery is a type of reuse that is suitable for degraded lands located at great distances from urban centers and main roads, while recreational, residential recoveries are suitable for degraded lands located at relatively short distances from areas of interest and roads. (Lazăr M. , 2010)

2.1.8 Criterion C8 - Investments for land recovery and rehabilitation

The existence of natural sources of flooding, the short distance from the areas of interest, the existence of permanent access roads and constructions that can be used for other purposes have important financial advantages.

Based on a classification existing in the literature (Lazăr C. , 2002), a new classification was developed adapted to the aim of the paper to ensures the evaluation (subjective, but which provides sufficient information) of the necessary investments regarding the recovery, rehabilitation and restoration of mining degraded lands and former open-pits (Figure 8).

2.1.9 Criterion C9 - Population requirements

In the process of planning the use of degraded land, it is necessary to involve all stakeholders: state, local authorities, local communities etc., in order to identify and establish uses and infrastructures appropriate to the type of land reuse. The demands of the population reflect the individual needs and priorities of local communities. (Lazăr M. , 2010)

The evaluation of population requirements can be done by different methods, one of the effective methods being the evaluation by opinion poll. Opinion polls should be aimed strictly at subjects who can benefit from the recovery and reuse of the mining degraded land, as well as researchers in the field.

Based on the results of the opinion polls and the hierarchy of population requirements, the method described below is applied to determine the score awarded according to this criterion, respectively to assess the flood opportunity (Apostu, Lazăr, & Faur, 2018):

- the value of a constant (c) is determined using Equation 2:

$$c = \frac{P_{max}}{n_{var}-1} \quad (2)$$

- the final score is determined using Equation 3:

$$P_f = (n_{var} - p_{lake}) \cdot c \quad (3)$$

where:
n_{var} - the number of reuse variants for the open-pit (offered in the questionnaire);
p_{lake} - the position of the “open-pit lake” variant in the hierarchy of population requirements;
c - constant;
P_f – final score.

2.2 Evaluation matrix

The 9 criteria established and described are the basis for the elaboration of a complex evaluation matrix that ensures the obtaining of results with a high degree of confidence, which makes the process of recovery and rehabilitation of a remaining gap to follow the optimal direction both ecologically and economically.

Depending on the described criteria, in order to evaluate the opportunity of flooding of the former open-pits, appropriate scores (P) were established with values between 0 and 3, where P = 0 characterizes the inopportunity of flooding of an open-pit, while P = 3 characterizes the major opportunity of flooding of an open-pit.

Figure 9 shows the matrix for evaluating the opportunity of flooding of former open-pits, in which are centralized the defined assessing criteria, respectively the scores according to different characteristics. To develop the matrix, numerous existing classifications in the specialized literature were taken into account, but also a series of evaluations and personal assessments made based on studies and researches conducted in the fields of Engineering and Environmental Protection and Mines, Oil and Gases.

The ecological benefits are not enough for the sustainable development of a region, so that appropriate research allows the choice of the most appropriate types of reuse, to complete the list of benefits from an economic, social, cultural etc. point of view.

3 RESULTS

Next, in order to verify the new methodology, elaborated for the evaluation of the flooding opportunity of the remaining gaps, the case of the lignite open pits from the Rovinari - Romania basin was considered. Currently, 5 lignite open pits are active in this basin: Rovinari, Tismana, Pinoasa, Roșia de Jiu and North Peșteana (Figure 10).

3.1 Assessing the opportunity of flooding of Rovinari Mining Basin lignite open-pits

Taking into account the established criteria and the complexity of the methodology and evaluation methods, the Rovinari Mining Basin open-pits were evaluated according to each criterion. It is worth mentioning that due to space reasons, the analyzes performed for each career in relation to each criterion could not be presented in detail.

- **Geomorphology and orography of the area (C1)**

From a geomorphological point of view, in the analyzed region, units of the Subcarpathians and the Getic Plateau are known. The mixed relief (hilly and meadow) predominates in three perimeters: Rovinari, Tismana and Roșia de Jiu, meadow in the North Peşteana perimeter and hilly in the Pinoasa perimeter. The lignite deposits were completely or partially below the level of the surrounding land.

The probability of resulting a remaining gap after the cessation of mining activity is relatively high in 3 of the 5 mining perimeters analyzed.

- **Configuration of the remaining gap (C2)**

The open-pits were evaluated according to their depth. For Pinoasa (current depth 80 m) and Roșia de Jiu (current depth 120 m) open-pits, the probability of occurence of a remaining gap is relatively low due to the extension of the quarries in hilly areas, respectively the extension of the interior dumps, which by the end of the activity can considerably reduce the final depth of the gaps (given that the inner dump covers the base and part of the in-situ slopes of the quarry) or can completely fill the remaining gap. Consequently, for the 2 remaining gaps, it was estimated that the final depth will be reduces, these presenting an reduced opportunity for flooding from this point of view. For Rovinari (maximum depth 75 m), Tismana (maximum depth 50 m) and North Peşteana (maximum depth 80 m) open-pits the depths will not show significant variations until the cessation of the activity, so these values can be taken into account for evaluation. (***, 2016-2019)

- **Necessity to restore the aquifer resources (C3)**

In order to establish the necessity to restore the aquifer resources in the area of the Rovinari Mining Basin, the types of adjacent land use to each open-pit were studied and based on their value (x), water requirements and water supply priority (defined through priority coefficient, c), the opportunity of flooding was assessed (Table 1).

- **Necessity of appearance of a water body in the area (C4)**

The economic specifics of Gorj County is an industrial-agricultural one. The economy of the city of Rovinari and of the adjacent villages has as promoter the extractive industry and the one producing electricity by burning coal (lignite), to which agriculture is added. The agriculture is non-performing economic branch at present, due to the fact that the agricultural area is of medium quality and a subsistence agriculture is practiced, with outdated technologies and equipments. Tourism is in its infancy, but has appreciable development potential. (***, 2010) The mining activity in the region is coming to an end, so we considered the agriculture and tourism as main fields of activity.

Given the major water requirements of crops and dry periods specific to the region, the occurence of a water body has many benefits, as an additional source of water for crops irrigation. (Nyari & Lazar, 2017)

- **Hydrology and hydrogeology of the region (C5)**

In order to estimate the contribution of precipitation to the flooding of the open-pits, the values of average annual precipitation and potential evapotranspiration recorded in the Rovinari area were taken into account (Figure 11). The value of evapotranspiration is given by the sum of the amounts of water that reach the atmosphere in the form of vapors through the processes of evaporation and plant transpiration. So, using the evapotranspiration in calculations provides relative but satisfactory information.

According to the annual amounts of precipitation (750 mm/m^2) and potential evapotranspiration (730-740 mm/m^2) in the area, results a surplus of water of about 10-20 mm/m^2/year, valid for all 5 open-pits, given their location (relatively small distance between them and similar climatic conditions).

The development of lignite deposit in the Jiu River meadow area, respectively in a region with impressive aquifer horizons, has a positive influence on the restoration of aquifer resources and flooding of open-pits, as it ensures the development of these processes naturally, without involving major financial investments.

In the studied perimeters hydrogeological conditions are generally difficult and very difficult. The assessment of flooding opportunity was made taking into account the value of the water inflow coefficient, which varies from one perimeter to another as it follows: 2.6 m^3/t for Tismana, 5.41 m^3/t for Rovinari, 3.7 m^3/t for Pinoasa, 16.32 m^3/t for Roșia de Jiu and 12,87 m^3/t for North Pesteana.

The geological formations consist of marls and clays (50-70%), sands (5-20%) and vegetal soil (5-20%), formations in which the lignite layers are incorporated. (Lazăr M. , 1998) So, aquiclude rocks predominates.

- **Stability conditions of the final slopes (C6)**

Based on the researches and documentations, observations and informations obtained in the field regarding the stability reserve of in-situ and dump slopes in the studied mining perimeters (Mihai & Onescu, 2015; Smeu, 2012; ***, 2016-2019), it was found that, in general, the slopes are stable. Thus, it was found that all in-situ slopes and the slopes of the inner dumps of the Roșia de Jiu, North Peşteana and Pinoasa open-pits presents high stability reserve, while the slopes of the inner dumps of the Tismana and Rovinari open-pits are at the equilibrium limit. So, for the final assessment, the most unfavorable values were taken into account, which increases the degree of safety and security of the objectives in the area of influence.

- **Accessibility and distance to the areas of interest (C7)**

According to the road quality map in Romania, the access roads in the studied area are: DN66 national road, with permanent asphalt, excellent condition, open to public traffic, easy access, intens traffic; DJ674 county road, with semi-permanent asphalt, mediocre condition, open to public traffic, easily accessible, low or medium traffic; DC73 communal road, with semi-permanent pavements, open to public traffic, low traffic. The connection with the open-pits is made through unpaved roads, difficult to circulate, closed to public traffic. The differentiation of the score was made taking into account the length of the connecting roads (*DN 66 - Tismana ≈ 3 km; DN66 - Rovinari ≈ 4 - 5 km; DN66 - Pinoasa ≈ 4 - 5 km; DN66 - Roșia de Jiu ≈ 1 km; DJ674 - Peșteana North ≈ 0.5 - 1 km*) and the shortest ones received a favorable score, as the costs of modernizing them are lower.

The smallest distances from the areas of interest for which the new land use can bring ecological and economic benefits were taken into account (Table 2).

- **Investments for land recovery and rehabilitation (C8)**

In order to evaluate the costs of land reclamation, the possibilities of flooding, the necessary measures for stabilization, modeling, revegetation of the land and the possibilities of reuse, modernization of existing constructions (buildings, halls, warehouses, etc.) or the construction of new objectives were taken into account and it was found that in the case of the Tismana and Pinoasa open-pits medium investments are required, while in the case of the other open-pits small investments are required.

- **Population requirements (C9)**

The assessment of the flooding opportunity of the Rovinari lignite open-pit was made taking into account the partial results obtained following an online survey, at regional level (Figure 12). Thus, the needs of the individual and local communities, the importance of socio-economic development of the region and the restoration of the environment were taken into account. (Apostu, Lazăr, & Faur, 2018)

Depending on the type of reuse of major interest in assessing the opportunity of flooding, namely "open-pit lake" and its position in the hierarchy of population requirements, the corresponding score was calculated (using Equations 2 - 3).

3.2 Final matrix

The scores obtained for the Rovinari lignite open-pits according to the assessing criteria allowed the construction of the final evaluation matrix (Table 3).

The final scores were determined by calculating the arithmetic mean, and based on this scores a hierarchy of the opportunity of flooding of the remaining gaps/former open-pits was established.

As a result of the assessment, based on the established assessment scale, the Rovinari lignite open-pit present the following flooding opportunity: North Pesteana open – pit – high/major opportunity, Rovinari and Roșia de Jiu open-pits – average opportunity and Tismana and Pinoasa open-pits – reduced opportunity of flooding.

4 DISCUSSIONS

The methodology developed for assessing the flooding opportunity of former open-pits, has a general character, can be applied to any type of open-pit and is an extremely useful tool for choosing the type of reuse of degraded mining lands, which can be used by both the economic operator and the companies designing the rehabilitation works.

The usefulness of the methodology consists in the fact that, although in many cases the creation of a lake in the post-mining landscapes is a desired solution, the concrete conditions are not always favorable. For example, even if the flooding of the remaining gap is possible in terms of available water resources, there is a risk of occurence of negative efects from geotechnical or ecological point of view on medium and/or long term. So, based on various assessing criteria, the methodology ensures a proper evaluation of the existing conditions and an appropriate assessment providing guidance on the open-pits that are suitable for flooding, while ensuring a high degree of security and safety of the objectives in the areas of influence.

Moreover, the methodology can be transposed into a telephone application or software, being very useful in this age of technology, which ensures a quick analysis of information providing feedback on the opportunity of flooding the analyzed open-pit.

Most of the negative consequences of an erroneous decision are eliminated as a result of the application of such a methodology, which takes into account a complex set of assessing criteria and a sufficient number of options. The more criteria are fulfilled, in the favor or to the detriment of the flooding and the creation of an open-pit lake, the more certain it is to obtain an optimal result and implicitly the mistakes in determining the direction of recovery of a former open-pit are insignificant and can be neglected.

By applying the methodology of a case study, it proved to be effective, the results obtained being plausible and applicable. As can be seen in the final matrix, North Pește̦ana open-pit presents a high opportunity of flooding as a result of favorable existing conditions, such as: development in the Jiu river meadow area, high depth of the open-pit (of 80 m), reduced investments since there are stable slopes, important inflow of water from precipitation and aquifer formations which contributes to the natural flooding of the open-pit, constructions which can take other functions, short distances to the surrounding localities, necessity of restoration of aquifer resources and of occurrence of a water body in the area, which have special advantages in terms of development and maintenance of newly installed vegetation on the degraded land, crops, orchards, restoration of water resources for local communities etc., and last but not least, compliance with the population requirement since the open-pit lake can take important functions such as lake for leisure and recreation or water reservoir for crops irrigation, especially in drier periods. Tismana and Pinoasa open-pits presents reduced opportunity of flooding primarly as a result of hydrological and hydrogeological conditions which are not favorable for flooding to which are added, depending from one case to another, instability of the slopes, reduced depth of the pit, population requirement, medium distances to the city etc., requiring high investments for creation of open-pit lakes so it is recommended to choose another type of reuse for this 2 open-pits.

The occurence of a water body, in an area that has never met such conditions before, implies microclimatic changes due to the increase of the amount of evaporated water. The vapors reach the atmosphere where they contribute to the formation of clouds, which in turn generate higher amounts of precipitation in the region or in the surrounding areas, depending on the atmospheric circulation. Microclimatic changes can be a disadvantage, because they contribute to the accentuation of the greenhouse effect, global warming, intensification of extreme phenomena, more violent storms, but for areas with a rainfall deficit, these changes are an advantage.

The advantages of creating open-pit lakes vary depending on the final type of reuse of the lake, so a number of common advantages are presented: the rehabilitation and reintegration of the degraded land into the landscape; the restoration of the aquifer resources, especially of the phreatic layer with advantages for the development and maintenance of the newly installed vegetation, crops etc.; establishment of a new ecosystem, an aquatic one and specific biodiversity; the restoration of adjacent ecosystems and local biodiversity; the restoration of drinkable water resources; source of water for irrigation of adjacent agricultural lands; sustainable development of the area; economic development (turism, pisciculture) and so on.

ACKNOWLEDGEMENTS

The research presented in this paper has been conducted within the RAFF project (Risk Assessment of Final Pits During Flooding) co-financed by the Research Fund for Coal and Steel (RFCS) under the Grant Agreement No-847299-RAFF.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests that could be perceived as prejudicing the impartiality of the research reported.

REFERENCES

Apostu, I. M., & Lazar, M. (2018). The importance of hydrographical, hydrological and hydrogeological conditions in the context of flooding of the remaining gaps. *Conference Proceedings, Ecology and Environmental Protection*, *18(5.1)*, pp. 933-940. Albena. doi:10.5593/sgem2018/5.1

Apostu, I., & Lazar, M. (2018). Possibilities of flooding of the remaining gaps of the quarries from the Rovinari Mining Basin. *Scientific Reports on Resource Issues, Holistic Approach in the Mineral Industry - Innovations in Geology, Mining, Processing, Economics, Safety and Environmental Management. 18(5.1).* Freiberg: Medienzentrum der TU Bergakademie Freiberg.

Apostu, I., Lazăr, M., & Faur, F. (2018). Researches regarding the population exigencies in the conditions of recovery and reuse of the remaining gaps of the quarries. *Mining Revue, 24*(4), 20-24.

Huidu, E. (2012). *Open-pit mining exploitation of coal deposits (in Romanian).* Târgu-Jiu: Măiastra.

Lazăr, C. (2002). *Economy, efficiency and financing of investments (in Romanian).* Bucharest: Economical.

Lazăr, M. (1998). Capitalization of thin layers in the open-pit exploitation perimeters in the Oltenia area (in Romanian). Petrosani, Romania.

Lazăr, M. (2001). *Surface water management (in Romanian).* Petrosani: Universitas.

Lazăr, M. (2010). *Rehabilitation of degraded lands (in Romanian).* Petrosani: Universitas.

Lazar, M. (2017). *Stability and Ecological Reconstruction of the Land Affected by Mining* (Vol. 63). Freiberg: Reports of Professorship Surface Mining.

Mihai, I., & Onescu, A. (2015). Geotechnical study for the hilly area on the advancing direction of Roșia de Jiu open-pit (in Romanian) (GEO-66/2015). Romania: Geoconsulting Design, Research and Development S.R.L.

Nyari, I. M., Lazăr, M., & Faur, F. (2017). Methodology for assessing the opportunities of flooding of the remaining gaps of lignite open-pits. *Conference Proceedings, Ecology and Environmental Protection*, *17(52)*, pp. 635-642. Albena. doi:10.5593/sgem2017/52/S20

Nyari, I., & Lazar, M. (2017). Flooding of the remaining gap of North Peșteana quarry in order to create a water reservoir for irrigations. 49(4), pp 9 – 19. Available from. *Research Journal of Agricultural Science, 49*(4), 9-19. Retrieved from https://www.rjas.ro/volume_detail/43

Păltineanu, C., Mihăilescu, I. F., Seceleanu, I., Dragotă, C., & Vasenciuc, F. (2007). *Aridity, drought, evapotranspiration and water requirements of agricultural crops in Romania (in Romanian).* Constanța: Ovidius University Press.

Rotunjanu, I. (2005). *Slope stability (in Romanian).* Petrosani: Infomin.

Rotunjanu, I., & Lazăr, M. (2014). Hydrological classification and evaluation of coal deposits . *Mining Revue, 20*(2), 7-14. Retrieved from http://www.upet.ro/revistaminelor/arhiva/rmpdf2014/nr2ro.html

Smeu, A. (2012). Efficient solutions for the construction and management of waste dumps in the Rovinari and Motru Mining Basins for rendering in the economic circuit (in Romanian). Petrosani, Romania.

***. (2010). Sustainable Development Strategy of Gorj County for the period 2011-2020. Gorj, Romania: Anexa nr.1 la Hotărârea Consiliului Local (H.C.L.) nr. 28/25.03.2010. Retrieved from file:///C:/Users/izabe/Downloads/Strategia_de_Dezvoltare.pdf

***. (2016-2019). Documentation Commercial Society Oltenia Energetic Complex - S.A. (O.E.C.). Rovinari, Romania.

***. (2020). *Road classification, Mobility and Transport*. (E. Commission, Producer) Retrieved 2020, from https://ec.europa.eu/info/index_en: https://ec.europa.eu/transport/road_safety/specialist/knowledge/road/designing_for_road_function/road_classification_en

TABLES

FIGURES