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# RESTORATION OF LANDSCAPES DEGRADED BY OPENCAST MINING IN THE AREA OF NORTHERN PODLASIE

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ABSTRACT: The article concerns the reclamation and revitalisation of post-mining areas in opencast mining. The article describes the reclamation of gravel-sand aggregate excavations located in the area of northern Podlasie. The primary challenge in the reclamation of sand pits is determining the development direction while considering the natural, technical, and economic aspects of the reclamation process. The main goals of this article are to emphasise the significance of reclamation studies and the necessity for different disciplines to simultaneously take into account the natural and cultural characteristics of post-mining landscapes from various points of view in order to produce the best possible landscape use planning for such areas.

KEYWORDS: reclamation, opencast mining, post-mining areas, northern Podlasie

## Introduction

Despite being a major global economic activity, mining has a detrimental effect on the environment. Opencast mining, in particular, is compelled to seriously degrade the ecological and aesthetic values of the landscape by its very nature. For the opencast mining's destructive effects to be relieved and the landscape and its immediate surroundings to be restored after the reserve's mining is finished, the altered land must be reclaimed.

The area of northern Podlasie has an extremely diverse landscape. Forested moraine hills are separated by valley depressions and overgrown meadows, especially in the eastern and north-western parts. This location is situated in what is known as Poland's "Green Lungs" because of the area's outstanding natural and scenic values. This region includes the Knyszyn Forest, which has a wide variety of trees.

The northern Podlasie area is located at the Masurian elevation, lying within the Eastern European platform. They reveal Pleistocene and Holocene deposits on the surface. The elevations of the surface relief are built by Central Polish glaciation settlements covering the entire area of the Podlaskie Voivodeship. Sands and gravels of terminal moraines and dead ice form numerous hills occurring throughout the study area. The height of the forms in which they appear is found up to 50 m. In this area, more than 20 deposits of sand and gravel aggregate have been documented (Bandurska-Kryłowicz, 1993).

Because there is no specific reclamation planning scheme for such landscapes and because it depends so heavily on the specifics of a given site, the reclamation of post-mining landscapes in this area is a very challenging task. Opencast mining techniques are frequently regarded as more economical, particularly when the mineral is present in a massive or wide body that is relatively close to the surface or when the mineral is present as part of the surface soil or rock. The most popular surface mining techniques, including strip mining, open pit mining, opencast mining, and quarrying, begin at the earth's surface and maintain surface exposure throughout the extraction process. Surface disturbance has a significant impact on the soil, surface water, fauna, and flora, which influences all types of land use (Sklenicka & Kasparova, 2008).

The article's main goal is to demonstrate, using the Podlaskie Voivodeship as an example, the significance of reclamation research and the requirement that various scientific disciplines simultaneously take into account the natural and cultural characteristics of post-mining landscapes from various angles in order to obtain the most suitable landscape for use in such areas. In order to prove this, the article reviews the effects of opencast mining activities on both the environment and human health. A wider view is given to the problem of post-mining land reclamation, which includes the definition of key terms, the goal, significance, and requirement of reclaiming open-pit mining areas, strategies and tactics, evaluation of reclamation success, the multidisciplinary nature of the problem, multiple case studies, and legislative considerations.

## Literature Review

The extraction of gravel-sand aggregates is crucial to the regional and global economies, but this process causes serious environmental harm and significantly alters the potential of the original landscape. As PIG (2023) points out, although gravel and sand aggregate extraction is regulated across the nation, Lower Silesia and north-eastern Poland have a concentrated supply due to the resource base's continued existence. So far, the majority of mines have carried out reclamation as part of their own activities, and only a few-in a commissioned system.

One of the most significant environmental effects of opencast mining is soil destruction. Original soil is lost or covered by wastes while the desired mineral material is being removed. Topsoil, in particular, needs to be conserved during and after mining because it is a crucial source of seeds and nutrients and should be kept for use in reclamation. Reclamation through macro levelling of excavations and profiling of slopes, drainage with a network of drainage ditches and soil restoration by spreading large amounts of topsoil turned out to be an ineffective and extremely expensive method (Mummey et al., 2002; Sypniowski, 2008).

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In addition, opencast mining accelerates soil erosion and sedimentation, which is usually preceded by soil weathering, and in this case, short but intense storms may disturb the existing stratification and increase the vulnerability of the land to erosion resulting from opencast mining (Sengupta, 1993).

According to Ghose (2002) opencast raw material mining produces significant environmental pollution, especially when it comes to dust and gaseous pollutants that worsen air quality. In the mining area and the surrounding areas, it causes air pollution issues.

As indicated by Gawałkiewicz (2020), in the climatic conditions prevailing in Poland and with the dominance of loose sands during surface exploitation, the soil-forming capacity of the removed humus or peat layer quickly loses, e.g., as a result of mineralisation and hydrophobization.

Moreover, as a result of the exploitation of natural aggregate deposits, water reservoirs are created, which development is not clearly specified. These tanks can be used as a drinking water intake, industrial water intake, fish pond breeding, recreational reservoir, or element of landscape composition. Each of these functions requires different parameters and a specific environment. Necessary is, therefore an analysis of environmental conditions that will specify the target development of workings (Bobrek & Paulo, 2005).

Before choosing the revitalisation and future function of the revitalised area, it is important to analyse the area undergoing revitalisation in terms of a number of factors. Diversification of the methods and functions of the revitalisation of post-mining areas is highly desirable, as it leads to the creation of positive synergies and reduces the risk of the revitalisation process at all levels (Kryzia & Kryzia, 2017). In addition, the analysis of the regulations governing the reclamation of mining land and examples of existing reclamation of mining land and sand and gravel mines show that the regulations are not consistent and do not provide a uniform standard for planning and carrying out the reclamation of mining land, which causes additional work and expenses (Chodak, 2013).

## Mineral deposits occurring in the northern Podlasie and their economic characteristics

The Nowowola Sheet covers the north-eastern area of the Podlaskie Voivodeship between longitudes 23°15’ and 23°30’ east and 53°20’ and 53°30’ north latitude. In administrative terms, the area in question covers two counties: Sokółka and Białystok. The Sokółka district includes the western part of the commune and the city of Sokółka, the eastern part of the commune Janów and the southern part of the Sidra commune, and in the Białystok poviat a small, northern part of the Czarna Białostocka commune. Settlement is concentrated mainly along roads, and most of them are rural settlements (Figure 1). The area covered by the sheet is located in the North Podlasie Lowland, at the junction of two mesoregions: Wzgórza Sokólskie (mostly) and Wysoczyzna Białostocka (south-western fragment).

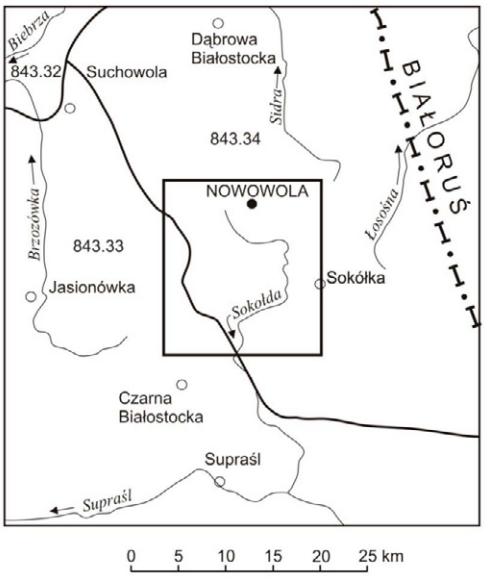


Figure 1. Location of the Nowowola Sheet
Source: Kondracki (2002).

The area covered by the sheet is located in the North Podlasie Lowland at the junction of two mesoregions: Wzgórza Sokólskie (mostly) and Wysoczyzna Białystok. The area is mostly part of a vast undulating moraine plateau, raised to a height of 150 to 200 m above sea level. The reliefs of the plateau are diversified by terminal moraines and dead ice moraines, which are well-preserved hills and mounds, and the height of the highest of them exceeds 208 m above sea level. Hills and mounds of dead ice moraines occur most often in the hinterland of two main sequences of

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terminal moraines. The largest concentrations of these forms are found in the region towns: Chwaszczewo, Plebanowce, and Racewo in the northern part of the area, in the vicinity of Rudawki, Ostrynki in the western part, and around Kantorówka and Stara Rozedranka in the western part of the area. The relative height of the forms reaches up to 15 m. The geological structure of the area is presented on the basis a detailed geological map of Poland at a scale of 1:50,000 in Figure 2.

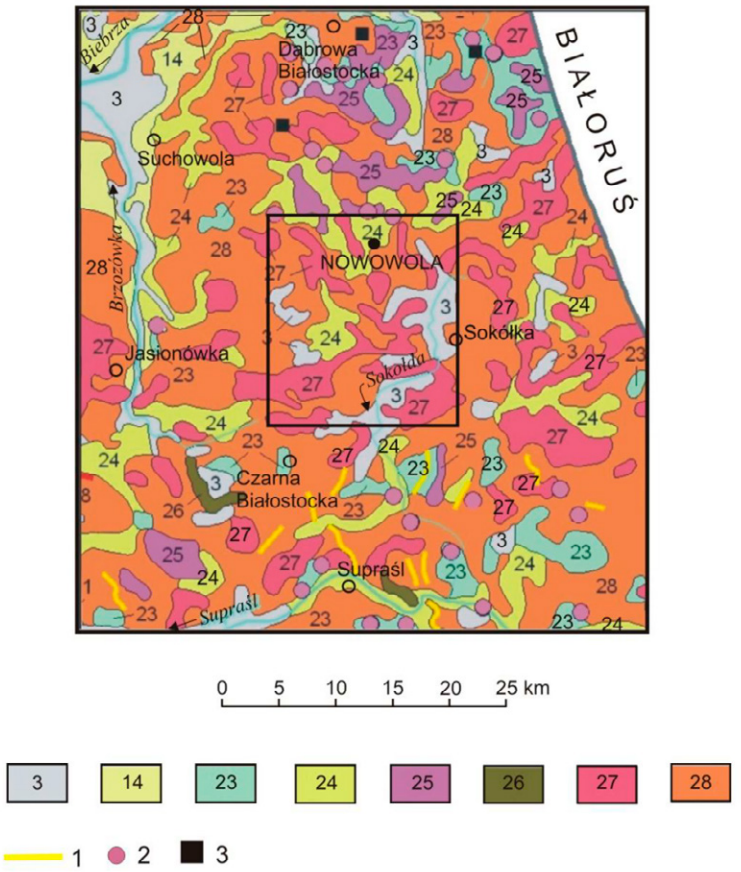


Figure 2. Location of the Nowowola Sheet:

1 – eskers; 2 – kames; 3 – sands, gravels, alluviums, alluvial peats (Holocene); 14 – outwash sands and gravels (Pleistocene); 23 – clays, reservoir sands; 24 – sands, outwash gravels; 25 – sands, kame silts; 26 – sands, silts, gravels of eskers; 27 – gravels, sands, boulders, clays of terminal moraines; 28 – tills, glacial sands and gravels.

Source: Kmieciak (2005).

Metamorphic rocks of the Eastern European Platform were found by drilling east of Sokółka. They consist mainly of Proterozoic gneisses and migmatites occurring at a depth of 420–450 m. Above these formations, at a depth of 203 m, there is a cover of Mesozoic sediments composed of Middle Jurassic sands and limestones, Upper Jurassic and Cretaceous glauconitic sands, and chalk. In the central part of the area covered by the map, Mesozoic deposits occur directly beneath Pleistocene deposits. In the rest of the area, chalk deposits cover the tertiary sediments formed in the form of glauconite sands and sandy muds with fine interlayers of brown coal.

Pleistocene deposits in the studied area are characterised by the presence of several levels of glacial erosion. Glacial deposits refer to the oldest glaciations – glaciers of the Narew River; southern Poland – glaciers of the Nida, San 1 and San 2; and central Poland – glaciers: Odra and Warta. Glacial sediments are separated by intermoraine deposits of the Augustan and Eemian interglacials. The deposits of the Narew glaciation consist of sands, gravels, and clays lying on them tills deposited in the largest depressions of the Quaternary basement. Confirmed the thickness of the sediments in the Bogusze borehole (in the central part of the sheet) is approximately 50 m. They were covered with sediments of the Augustan interglacial in the form of silts, river and lake sands, and gravels up to 10 m thick. In the hole In the south of the discussed area, the Augustów interglacial settlements lie in the wetland directly on tertiary formations (Stupnicka, 1997).

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Nida glaciation deposits in the Nowowola region are present from 75 m above sea level to about 20 m above sea level and reach a thickness of approximately 50 m. The top of sediments in San Glacier 1 occurs at an elevation of approximately 60 m above sea level and their thickness reaches up to 10 m. A characteristic feature of this profile is the presence of mud reservoirs in the northern part of the area at a depth of about 125 m and a thickness of approx. 10 m. All sediments from San Glacier 2 are approximately 35 m thick, and their recorded ceiling occurs at a depth of 90 to 110 m below sea level. Sediments of the Central Polish glaciations cover the entire area and build up surface relief facades. Settlements of the lower stage and the middle one were developed in the form of backwater silts, clays, sands, glacial gravels, and boulder clays. Maximum thickness of sediments in the lower stadium is about 65 m, and the middle stadium is 50 m. The sands and gravels of terminal moraines and dead ice create numerous hills occurring throughout the entire examined area. The height of the forms in which they are located is up to 20 m. End moraines are composed of fine- and medium-grained sands with gravels and gravels layered diagonally in gutters on a large scale. Near the culmination of the moraine hills, boulders with a diameter of up to 1.5 m are often found in Racewo and Geniusze aggregate mining plants, which obtain significant amounts from the sludge in question.

There are currently 7 deposits being exploited in the area on the basis of granted concessions. Areas and mining areas have been designated for these deposits. Mineral extraction is carried out in open pits and in slope-deep mines, and exploitation is or will be carried out at two mining levels.

The "Racewo" deposit is exploited continuously under a license issued by the Białystok Voivode, valid until 2090. An area has been established for the deposit mining area with an area of 84.6 ha and the mining area with an area of 93.8 ha. Exploitation is carried out on multiple levels and then subjected to dry and wet sorting. In the described deposit, a fraction of 2-16 mm is used to produce concrete; thicker fractions are crushed to these dimensions. The aggregate is transported to recipients by truck. As a result of exploitation, two slope-deep workings were created in the northern and western parts of the deposit, with an area of approximately 10 ha and a height of mining slopes of approximately 18 m. The northern working in its eastern part was reclaimed in a basic form by pushing the overburden, levelling the area, and planting legumes from the admixture of grass. As a result of the exploitation of the western working, a slope-deep excavation was created with an area of approx. 3 ha. The excavation wall is up to 12 meters high. Reclamation of the excavation will be carried out in the forest direction.

The "Sierbowce" deposit was exploited on the basis of a concession from the starosta of Sokółka, valid until 2025. Mining area 20 has been established for the deposit with an area of 1.1 ha and a mining area with an area of 1.4 ha. The aggregate is mined continuously and transported to the recipient. As a result of exploitation, a deep excavation was created with an area of approximately 1 ha. The excavation wall is up to 7 meters high. Reclamation of the excavation site is carried out in the forest direction.

The mineral from the "Hało" deposit is exploited on the basis of a concession from the starosta of Sokółka, valid until 2027. The user of the deposit is a private person. A mining area of 1.3 ha and a mining area of 2.3 ha have been established for the deposit. The deposit is exploited periodically for the recipient's own needs. As a result of the exploitation, a slope-deep excavation with an area of approximately 1 ha was created. The excavation wall is up to 6 meters high. Reclamation of the excavation will be carried out in the forest direction.

The "Geniusze II" deposit is exploited periodically pursuant to a concession decision of the Marshal of the Podlaskie Voivodeship, valid until 2029. Three areas have been established for the deposit mining areas, with a total area of 12.68 ha and 2 mining areas, with a total area of 13.93 ha. The user of the deposit is a private person. The deposit is currently being exploited in fields west and southeast. The excavation in the western field has an area of approximately 3 ha, and the height of the exploitation slopes is approximately 6 m. Field excavation in the southeastern area exceeds the area of the deposit field and is approximately 3.5 ha, with the height of the exploitation slopes approximately 12 m, and the exploitation is moving towards the northern field. There is an excavation in the northeastern field, currently closed, with an area of approximately 0.6 ha and slopes up to 4 m high. Mineral after extraction is sorted and then transported to the recipient. The excavation will be recultivated and led towards the forest.

The "Geniusze V" deposit is periodically exploited under a license from the voivode Podlaskie valid until 2026. A mining area has been established for the deposit of 2.7 ha and a mining area of 2.8

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ha. The user of the deposit is a private person. The excavation in the deposit has an area of approximately 0.6 ha, and the height of the exploitation slopes reaches 4-7 m. The deposit will be reclaimed towards the forest.

The "Janowszczyzna III" deposit was exploited continuously under the concession Starosta of Sokółka valid until 2014. A mining area has been established for the deposit with an area of 1.95 ha and a mining area with an area of 2.04 ha. The user of the deposit is a private person, and the mineral after extraction is transported to the recipient. Excavation on the deposit has an area of approximately 0.3 ha, and the height of exploitation slopes up to 4-6 m. The method of reclamation of the deposit is not specified. Several deposits, despite obtaining exploitation licenses, have not yet been developed.

Individually, the workings vary in shape and size and are exploited to varying degrees. Some of them undergo slow self-reclamation; some of it is also a place of illegal storage waste. In these points, sand and gravel minerals predominate and are highly variable lithologically under the overburden of soil approximately 0.5 m thick. Mineral in places is contaminated with clay inserts and the way it occurs is nested or lenticular.

## Principles of land reclamation and development in Polish law

In accordance with the Act on the Preservation of Forest and Agricultural Land (Act, 2024), land that has lost its agricultural or forest character due to non-forest or non-agricultural activities is susceptible to development and replanting. It is important to note that carrying out industrial activities on these lands can result in their disappearance, as well as the disappearance of nearby land. When it is anticipated that industrial operations will negatively affect the environment, land reclamation and development should be initiated. Land reclamation should begin as soon as industrial activity is no longer required on the property and be finished no later than five years after activity has ended or has been abandoned entirely, partially, or for a predetermined amount of time. Vegetation, agricultural crops, and trees should be kept in good condition on land required to carry out industrial activities but not occupied by structures or machinery associated with these activities. Development of the land should start as soon as land reclamation is finished. At every level of industrial activity, land reclamation and development should be planned, designed, and carried out in accordance with the reclamation and development documentation, which is part of the investment and operational documentation.

The suitability and soil characteristics of subsurface formations, the toxicity and physical and chemical properties of land and water, as well as other aspects of the natural environment required for cultivation and development, must all be determined during the course of geological and research work related to an industrial investment. In order to properly reclaim land, it must be shaped, hydrological conditions must be controlled, biologically significant land layers must be preserved, soils must be restored, neutralised, or fertilised, pioneering vegetation must be introduced, slopes must be embanked, and the necessary network of access roads must be rebuilt or constructed. Agrotechnical techniques for proper soil formation, additional water and drainage systems, and the building of additional auxiliary structures and machinery are all part of land development.

The initial stage of reclamation preparation entails figuring out what factors influence whether development and reclamation solutions are succesfull, steering land development in the direction of the intended use, and incorporating the plans for development and reclamation into the investment's technical and financial assumptions or into simpler documentation.

The fundamental reclamation phase entails reshaping the land and controlling the hydrological conditions of the reclaimed area as well as its environs, utilising biologically valuable soil layers for forestry or agricultural purposes, gathering inputs and waste from mining or geological work as well as other waste from heaps, landfills, and dumping areas in a way that will maximise future development potential, and restoring soils through technical methods if necessary to build or rebuild necessary access roads, fertilise barren formations, or neutralise or effectively isolate toxic formations.

The most crucial stage of the land reclamation project is the detailed reclamation phase. Biological or biological-technical reconstruction of slopes and strips of land at their foot and on the crown, neutralisation of toxic formations and fertilisation of barren formations, introduction of vegetation

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that recreates biological conditions and inhibits erosion, and, in the event of land development for water management purposes, construction of the necessary hydrological facilities and devices aimed at protecting water against water loss or pollution, as well as the start of water storage, are all included in this process.

Local spatial development plans should be taken into consideration when determining the direction of land development, which should also take into account the terrain, geological, hydrological, technical, economic, and social conditions of the land intended for agricultural, forestry, water, municipal, or other purposes.

The appropriateness of land, water, and other significant components of the natural environment should be considered in elaborating the plan of land regulation and development.

It should specifically include the following information:

1) the current state of the environment based on an inventory of natural conditions, including hydrological conditions, conducted prior to the start of industrial activity on land affected by this activity,
2) anticipated alterations in the environment – predicated on the evaluation of the influence (both direct and indirect) of industrial operations on the environment and the findings of an economic examination of the feasibility and wisdom of mitigating the adverse consequences of said operations,
3) strategies to mitigate the adverse effects of industrial operations on the environment, considering the handling and application of waste and byproducts,
4) suggestions about the course of land development and how it should be carried out, specifically about the utilisation of biologically valuable soil layers and the removal of hazardous, combustible, and other formations that obstruct reclamation and development,
5) the process of providing financial resources for reclamation and development works, investment implementation, investment operation, and termination of industrial activity,
6) technical and economic indicators of reclamation and development,
7) how to finance the reclamation and development projects,
8) strategies for mitigating risks on the reclaimed land,
9) a timeline for land reclamation and development that is tailored to the phases of investment implementation, investment operation, and industrial activity termination contractor for the reclamation and development projects.

## Economic Decision-Making Model for Reclamation

In order to decide on the recultivation of disturbed land gravel and sand extraction, a three-stage decision-making process was proposed (Andersen & Coupal, 2009).

The first stage – recultivation and preparatory stage – should include the classification of workings, then the assessment of soils lying on the top of the deposit in order to protect them for subsequent agrotechnical improvement, carrying out soil and habitat tests at the bottom of the workings, and, finally, the development of technical documentation.

During the second stage of raw material extraction, the operator is responsible for ensuring the project complies with national regulations for the entire period of deposit exploitation, including interim and final reclamation activities. The objective function related to the optimal level of compliance of the operator's actions with the regulations can be written as:

$$\min C = I(e) + R(e) + F(e) \tag{1}$$

where:
C – cost of compliance,
I – interim reclamation (reclamation costs incurred prior to the end of production),
R – final reclamation (plugging and surface reclamation activities performed after production has ended),
F – fines,
e – regulatory compliance effort.

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The variable value in the presented model is the level of effort related to compliance with regulations, denoted as e. This variable includes hours of human labour and equipment devoted to activities related to land reclamation and adapting it to applicable regulations. This function can be presented depending on the variables in the form of a diagram presented in Figure 3, in which the horizontal axis represents the economic effort related to adapting the excavation to the applicable regulations.

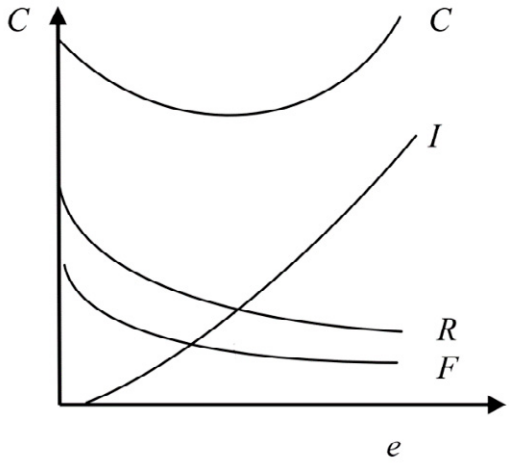


Figure 3. Function of the cost minimisation problem
Source: Andersen and Coupal (2009).

Stage three: decision on recultivation When mining is completed, the operator decides to recultivate the occupied area or leave it without recultivation completely. This decision depends on the costs of final remediation R(e), in relation to environmental fees and penalties (P) and reputational costs (R):

$$C = \min (R(e) + P + R) \quad (2)$$

It is clear from this model that there is an increase in *P* or *R* costs, a decisive factor influencing the decision to recultivate the deposit. Moreover, in the case of small mining plants, the impact of reputation on recultivation costs is small. Larger companies are much less likely to declare bankruptcy and terminate their contracts than smaller operators. This means that for most if not all, larger producers, the threat of suspension of operations due to fines or loss of reputation is the decisive enforcement mechanism.

## The process of legalizing the exploration and documentation of mineral resources in Poland

The primary modification to the legalisation of mineral deposit exploration and documentation brought about by the Geological and Mining Law Act of 9 June 2011 is the new law's waiver of the requirement to secure concessions when exploring or recognising mineral deposits other than those that are covered by mining property. For aggregate deposits and rock raw materials that are covered by the right of title to land property, such concessions are, therefore not required today.

However, activities related to searching for and exploring the deposits of interest to us have not been deprived of administrative supervision. Instead of obtaining a concession, we must approve a geological works project (Articles 79 and 80 of the Act of 9 June 2011). This is done by way of a decision issued by the voivodeship marshal or the starost, respectively. The division of competencies is similar to the previous one. The starost considers applications related to mineral deposits (not covered by mining property) searched for and explored in an area of up to 2 ha for the purpose of opencast extraction, in the amount of up to 20,000 $m^3$, in a calendar year and without the use of blasting agents.

In other cases, applications are submitted to the voivodship marshal (Article 161). Such a geological works project, in terms of its substantive content, corresponds to the former "geological works project". However, there have been changes in both the procedure for its approval and the content of this document (compared to the geological works project).

When preparing a geological works project, it must be remembered that it contains additional elements specified in the Regulation of the Minister of the Environment of 20 December 2011 on

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detailed requirements for geological works projects, including works whose performance requires a concession, in force since 1 January 2012.

According to this regulation, the description of the work site's location must include information such as land development and protected facilities and areas. Elements concerning the liquidation of excavations should also include information on land reclamation. The content must include a description of the impact of the intended geological works on protected areas, including Natura 2000 areas, referred to in the Nature Conservation Act. A new graphic attachment is a geological and economic map presenting the components of the environment subject to protection, drawn up on an appropriately selected scale no smaller than 1:50,000.

The detailed content of the geological documentation of the deposit is currently specified in the Regulation of the Minister of the Environment of 22 December. It came into force on 1 January 2012, and its content has changed in relation to the legal act previously in force.

Regarding the procedures for approving the geological works project in line with this regulation, consideration should be given to the requirement that, in line with Article 80 paragraph 5, the body making the decision seeks the commune head's (mayor or city president) opinion.

A new provision is one indicating which entities are considered parties in the proceedings on approval of the geological works project (Article 80, paragraph 3). These are the real estate's owners (perpetual users) within the boundaries of which the geological works are to be performed. When determining the parties and providing them with information on the proceedings, the provisions of Article 41 of the Act shall apply accordingly. They state, among other things, that the parties are not the owners of the neighbouring real state. Moreover, when the number of parties exceeds 20, the administrative bodies shall notify about decisions and other activities by means of announcements.

The planned geological works cannot, therefore, violate the intended use of the property specified in the local spatial development plan and in separate regulations. In the absence of a local spatial development plan, the activity cannot violate the manner of using the property established in the study of conditions and directions of the spatial development of the commune and in separate regulations.

Commencing geological works requires submitting a notification of the intention to commence them (Article 81). The notification should be addressed to the geological administration body, the commune head (mayor, city president) and in the maritime areas of the Republic of Poland, the local maritime administration body, and the mining supervision body. A novelty is the rule that the notification to the mining supervision body is made when the requirements concerning the operation of a mining plant apply to geological works.

The notification, as before, should be made no later than two weeks before the intended commencement date of geological works. The data that should be included in the notification has been specified. In addition to the commencement and completion date of works, indication of their type, and basic data concerning them, we provide the names and surnames of persons exercising supervision and management, as well as the numbers of certificates regarding their qualifications (previously, it was written generally about indicating the data of the above persons). The new act states that the obligation to document the course of geological works and their results is assumed by the person who received the decision approving the geological works project or the concession (Article 82, paragraph 1, point 1). Hence, the conclusion is that the investor (entrepreneur) must now ensure the creation of geological documentation.

It should be added that no mining plant operation plan is prepared for geological operations aimed at searching for or recognising mineral deposits, conducted without the use of blasting agents, at a depth of up to 100 m outside the mining area (Article 105, paragraph 2, point 2). Operations are then conducted on the basis of a concession or a decision approving the geological operations plan.

The chapter on the list of mineral deposit resources should include their division into resources that meet the limit values of the parameters defining the deposit balance sheet and those that do not – off-balance sheet (in the case of their documentation). The results of specialist research in the case of geophysical research should be presented in the form of computer data carriers containing the location of the works, source data, and processed data. The content includes an unambiguous statement that for solid mineral deposits, the degree of recognition of the deposit in category C1 should be sufficient to develop a deposit development project.

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If the results of the exploration and recognition works were unsuccessful and we were unable to document the deposit, we still prepare the so-called "other documentation," i.e., documentation of the performance of geological works not ending with documenting the resources of the mineral deposit or water resources.

This documentation is to be prepared in a single paper copy and 3 digital copies within 6 months of the completion of the work and submitted to the body that granted the concession or approved the geological works project (Article 93, paragraph 8); it does not require approval by a decision (Article 93, paragraph 7). Ultimately, the body forwards the submitted copies of the documentation to other locally competent geological administration bodies for archiving (one archive itself). The detailed content of the discussed documentation is currently described in the Regulation of the Minister of the Environment of 15 December 2011 on detailed requirements for other geological documentation.

The Act of 9 June 2011 – Geological Mining Law contains provisions on the mandatory introduction of documented mineral deposits by the municipal authorities into planning documents. According to Article 95, they should be disclosed in the studies of conditions and directions of spatial development of the municipality, local spatial development plans, and spatial development plans of the province. The area of the documented mineral deposit is to be mandatory introduced within two years (from the date of approval of the geological documentation) into the studies of conditions and directions of spatial development of the municipality. If this does not happen, this action will be carried out by the governor under a substitute order, and the costs of this will be charged to the municipality (Article 96). The municipal authorities will learn about the fact of approval of the documentation by receiving copies of the decisions approving them from the geological administration authorities, which is required by the Act (KierunekSurowce.pl, 2024).

## Reclamation of post-mining landscapes in the North Podlasie Lowland on the example of Bobrowa open-pit mine

North and Eastern Podlasie is one of the most beautiful and least polluted areas in the Podlaskie Voivodeship. Because of the richness of the natural environment, this is a unique area. In comparison to other regions of the country and the European Union, air purity and little human influence in the environment offer this place adequate individuality and a sense of extraordinary climate and unique character. It is a land of forest complexes, naturally preserved river valleys, and a harmonious agricultural and cultural landscape. Protected areas of various ranks prove their natural value. The most valuable ones include the Knyszyńska Forest Landscape Park, the "Wzgórza Sokółskie" Protected Landscape Area, protected areas of the European Ecological Network NATURA 2000 (special protection of birds and areas of protected habitats), and nature reserves and monuments. Natural or near-natural vegetation groups (forests, swamps, peat bogs, and natural meadows) cover considerable expanses in this area, and the same amount is covered by areas with a preserved harmonious agricultural cultural landscape, with a predominance of traditional, low-intensity agriculture.

Due to the very high natural values of the studied area, the reclamation of post-mining areas should aim to create a landscape that will not deteriorate the existing state of the natural environment in terms of aesthetics and ecology, will be coherent with the surrounding intact area, and will be as useful and versatile as possible for future generations.

Mining and land development are inextricably intertwined in a dynamic and integrative process impacted by a variety of environmental, production, aesthetic, land use, and economic concerns related to reclamation planning objectives. This process begins when a mine opens and concludes when it closes, which can take anywhere between five and fifty years (Bell & Donelly, 2006).

In order to recultivate the post-mining area in accordance with the existing natural environment, the surrounding area's natural and cultural factors must be considered.

Given the above conditions, the basic objectives of recultivation of excavations remaining after the extraction of gravel and sand in the Podlaskie Voivodeship should include:

- removing health and safety hazards (i.e., removing any buildings, machines, and structures that endanger human health and safety),
- restoration of exploited land and water resources (i.e., progressive regeneration of vegetation, restoration of sustainable soil and water conditions),

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- reducing the environmental impact of mining outside the plant (i.e., restoring locations associated with the storage and transit of excavated material to their original condition),
- ensuring that post-mining areas have a real, self-sufficient future, taking environmental and socioeconomic factors into account (for example, development of publicly owned land for recreation, care for historical areas, implementation of environmental protection goals, or ensuring benefits related to open space and construction of public utility facilities in municipalities),
- promoting better use of energy and natural resources and assuring sustainability in mining activities. With the implementation of environmental conservation and land reclamation programs to minimise the negative environmental effects, special attention must be paid to the post-mining use of the land and its potential functions (i.e., pasture, hayland, recreational areas, wildlife habitat, wetlands, fishing ponds, etc.) in order to obtain satisfactory results in reclamation.

Natural factors that should be taken into account for the purposes of reclamation and post-mining area development planning include (Vallauri & Dudley, 2005):

- terrain topography (relief, slope),
- climate (growth season, humidity, wind patterns and intensity, temperature, precipitation, and flow patterns),
- hydrology (surface hydrology, groundwater, flood plain boundaries, aquifers, quantity and quality of runoffs, potential for recharge, and patterns of surface drainage),
- geology (including geomorphology, structure, stratigraphy, and the chemical makeup of the overburden and raw materials),
- soil (structure, permeability, erodibility, bearing capacity, pH, depth to bedrock, organic matter content, and texture),
- terrestrial ecology, which includes native and migratory birds, crops, animals, aquatic animals and plants, and rare and endangered species.

The following cultural elements must also be considered for remediation purposes:

- location (accessibility, transit networks, adjacent land use, land use plans, and land ownership),
- the type of usage (commercial, industrial, residential, forestry, recreational, and agricultural) and its significance,
- population characteristics (population change, density, age distribution, household size and number, average income, employment, and level of education).

The Bobrowa open-pit mine is located in the Zabłudów commune in the Podlaskie Voivodeship. The mine's deposit is made up of sand mixed with gravel and sands with a gravel admixture, with thicknesses varying from 4.6 to 17.0 meters (Figure 4).

Figure 4. The Bobrowa open-pit mine Bobrowa II

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The top of the deposit layer is, on average, 173.3 m above sea level. The deposit layer is composed of interwoven sand gravel, gravel sand, and sand with an admixture of gravel. They are brown and grey-brown in the roof part and grey in the floor part. The deposit layer includes sand with an admixture of gravel occurring in the roof or interlayering sand and gravel deposits. The deposit layer's average thickness is 27.0 m, with a range of 4.6 to 47 m. For the deposit layer, the average sand point varies from 34.9% to 68.4%, with an average of 53.4%. The deposit is exploited on two levels. The first level is the water-free layer, while the second level is the water-bearing layer of the deposit. The thickness of the dry layer ranges from 4.6 m to 21.4 m, and on average 11.4 m. The sand point for the dry layer varies from 28.9% to 78.2% and on average 54.0%. The thickness of the flooded area ranges from 3.7 m to 30.0 m, and the average is 19.0 m. The sand point for the waterlogged layer is slightly lower than for the dry layer and ranges from 14.1% to 70.0% and on average 52.9%. Gravel-filled sands that form a deposit series are found on silty or fine-grained sands, as well as occasionally on clay. Four approaches can be applied to the reclamation of open-pit sand and gravel mines. Reclamation that occurs only after the mine's entire resource supply has been exhausted is known as post-mining reclamation. Temporary reclamation to stabilise disturbed areas is known as interim reclamation. Simultanous reclamation occurs concurrently, gradually, or continuously involves replacing soil and overburden as soon as minerals are removed. Segmental reclamation is the process of reclaiming land after a mine's mineral reserves are depleted (Figure 5).

Figure 5. Segmental reclamation in Bobrowa open-pit mine

The current process for mine Bobrowa recovery is following the depletion of all available resources from the entire area. Although it might be required at some sand and gravel deposits, this kind of activity is the worst method since it leaves large areas untreated for extended periods of time. The primary drawbacks of this method are that it degrades the soil during the mineral extraction process, making it less fertile than the original soil, and it will likely take longer and cost more to plant new vegetation.

The basis for spatial planning in the commune is the spatial development plan aggregate deposits Bobrowa adopted in 2023. The area covered by the plan is located in the Natura 2000 area – Special Protection Area for Birds (OSO) "Puszcza Knyszyńska (PLB 200003) and the Special Area of Conservation of Habitats (SOO) "Ostoja Knyszyńska (PLH 200006).

This area also includes the Knyszyn Forest Landscape Park buffer zone in the settlement-agricultural-forest zone. Each project implemented in the area of the plan requires the use of individual solutions to reduce negative impacts on the environment. This plan introduces a ban on locating projects that may significantly impact the environment. The adopted spatial development plan intro-

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duces an obligation to maintain natural vegetation until aggregate extraction begins, as well as a ban on storing waste, sewage waste in post-mining pits and seeping polluted water into the ground. In terms of environmental protection, this plan requires the successive recultivation of the mining area in parts of the area where extraction has already been completed.

In this plan, the area of the "Bobrowa" mining area and terrain was designated. The gravel mine is located on the southern side of National Road No. 65 (Figure 6). The forest direction is recommended for post-mining area reclamation in the spatial development plan. Reclamation of post-mining areas in the direction of forest, ecological or park is connected with the necessity of introducing vegetation. This requires proper preparation of the ground, designing the species composition of plantings, and performing fertilisation and maintenance procedures. The scope of necessary work depends on the type of aggregate extracted, extraction technology, and local natural conditions.

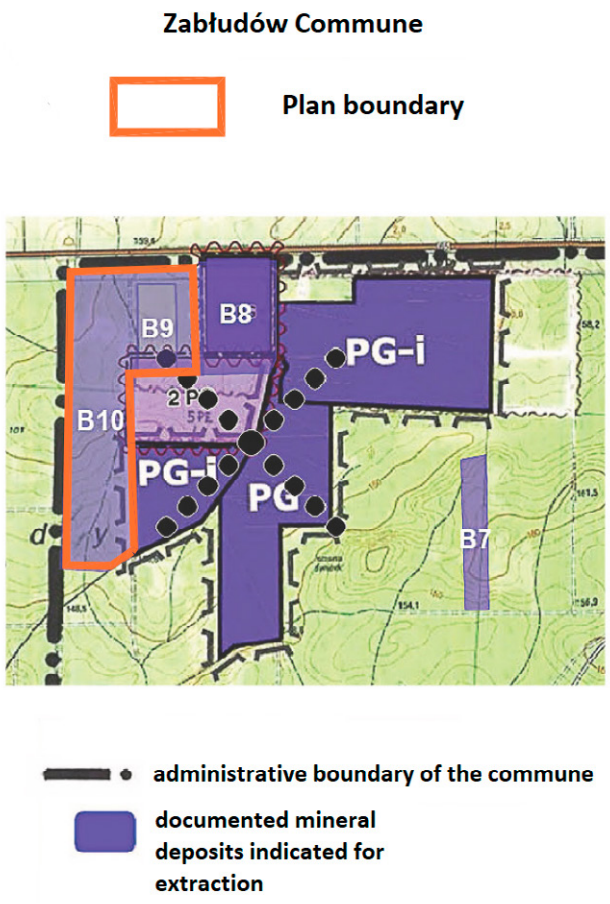


Figure 6. Spatial development plan
Source: Uchwała (2024).

The most laborious activity, but also the one that allows for the fastest reconstruction of the fertile soil layer on reclaimed land, is the selective removal of specific soil levels during access works (e.g. separate top levels – organic and humus, separate lower levels), then their separate storage and later use to recreate the soil profile. The top layer of the recreated soil can be additionally enriched with biomass from the fragmentation of tree trunks, branches and roots. The top layer of soil can also be removed in its entirety without separating individual genetic levels of the soil. In such a case, a single layer of soil is removed in which the content of soil humus is at least 1.5%.

The principles of introducing woody vegetation to the area of reclaimed wasteland, i.e. the species composition of plantings, the type of plant material and the technique and time of planting should be adapted to the specifics of the reclaimed object. When designing the species composition of plantings, the quality of the habitat, the functions to be fulfilled by the plants and their biological features should be taken into account. In the case of reclaiming for forest management, the natural and forest region in which the reclaimed object is located and the potential habitat type of the forest to be recreated should be additionally taken into account. In the case of planned water reservoirs, their reclaiming requires the introduction of aquatic and floating vegetation and reed beds. Such vegetation may appear through natural succession, but carrying out plantings significantly accelerates the process of overgrowing the banks of water reservoirs.

According to the Project of the reclamation of the excavation after the Bobrowa aggregate mine, the scope of reclamation will include: profiling the bottom of the excavation, removing or leveling the heaps of unused minerals, possibly reinforcing or leveling the peripheral slopes of the excavation. The scope of these works will be determined by the person supervising the reclamation.

In addition, the reclamation will include delivering neutral waste (mainly soil from excavations) to the excavation area intended for filling the excavation. These works will include storing the brought

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waste, its stabilisation, leveling the soil located on the dumps and removed before the start of mining works, and marking the boundaries of the plots. The target terrain shape results from the planned use of the area in the future by the owner of the plot, i.e. forest direction.

The target elevation of the reclaimed area was adopted at a level that would allow for harmonising plot 568 and part of plot 569 with the surrounding terrain and would allow for slopes with an inclination of no more than 3° which would allow for afforestation and maintaining the stability of the terrain. The target elevations are presented in the drawing part. The slopes were maintained in accordance with the terrain. The slope bordering the remaining area of the deposit will be made with a slope of up to 35°. The slope will be eliminated when the reclaiming works covering the remaining area of the "Bobrowa" quarry continue. The reclaimed area will amount to 14,672 $m^2$ after all the processes has been completed.

The mass balance carried out shows that in order to achieve the final and optimal shape of plots 658 and 659, it will be necessary to fill 108,639 $m^3$ of excavation with inert material or waste specified in the Regulation of the Minister of the Environment. The list of waste intended for use during macro-levelling includes concrete and brick waste from demolitions and renovations, soil, earth and stones.

In parallel with the forming works, the process of compacting the material used for macro-leveling should be carried out. Multiple passes with heavy equipment should carry out compaction. In this way, a stable mass will be obtained and wind processes will be slowed down. After the macro-leveling of the separated area of the Bobrowa deposit, a stabilized area will be created, poor in the soil-forming layer necessary for afforestation. For this purpose, a 1 to 1.5 m soil-forming layer is designed in the area of the excavation, allowing for the development of root systems of the planned afforestation. The minimum volume of material for the soil-forming layer will be about 15,000 $m^3$.

The Bobrowa mine reclamation project will also include biological reclamation aimed at introducing vegetation to the surface of the reclaimed area, which will limit the harmful impact of the facility on the environment. The planned tasks of biological reclamation are:

- creation of a soil-forming layer constituting a habitat for plants, which will constitute the basic protection of the reclaimed area,
- stabilization of the soil-forming layer and securing it against water and wind erosion, while at the same time providing appropriate aesthetic and landscape values,
- initiation and stimulation of soil-forming processes,
- absorption of rainwater in the root zone of plants, increasing terrain evaporation,
- creation of a phytosanitary zone for runoff water.

The area designated for reclamation and afforestation is located in the Knyszyńska Forest Mesoregion, where the dominant plant landscape is mixed coniferous forests and oak-hornbeam forests. The forest cover is very high and amounts to 71%.

The selection of species composition for afforestation should lead to the formation of target stands with a species composition referring to natural forest associations and/or to natural successional stages. These compositions should be complete, composed of both main, admixed and biocenotic species occurring in appropriate forms of mixing. The afforestation carried out will have the character of reproducing the natural habitat of a mixed coniferous forest with a characteristic stand of Scots pine, Norway spruce and silver birch appropriate for this region. In accordance with the Forest Management Principles – in the area where the potential habitat type of the forest will be a mixed coniferous forest, the species composition of the crop is designed to contain Scots pine – 80%, Silver birch – 5%, Norway spruce – 15%.

For afforestation, seedlings with a covered root system and mycorrhizal fungi implanted into the substrate should be used and then planted with the ball. A medium-deep full ploughing (about 30 cm) is planned, with soil loosening to a depth of 50 cm. It is advisable to prepare the soil in autumn in the year preceding planting.

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## Conclusions

In natural conditions, soil formation is a process that takes dozens or even hundreds of years. Its destruction can occur at a rate that is a hundred times faster. The mining industry contributes to the creation of large-area soilless post-mining areas. Through skillfully selected and applied reclamation activities, which eliminate defects characteristic of post-mining land, they are quickly (compared to the natural) transformed into soil. The emerging forest ecosystems determine the effective development of post-mining areas.

Success in rehabilitating or restoring forest ecosystems after extraction can be assessed by whether the recovered forest is productive and self-sustaining and meets ecological, economic, and social objectives. Achieving this objective relies on an integrated approach that includes:

- designing landforms that will support the desired long-term geotechnical stability and hydrological processes,
- carefully placing and handling overburden and surface soil materials to facilitate soil development and vegetation establishment,
- creating heterogeneity at different scales; matching topography, overburden, surface soil, and vegetation to support the development of a diversity of forest ecosystem types,
- encouraging natural regeneration in combination with the use of surface soil materials, seeding, and planting of native species.

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## REKULTYWACJA OBSZARÓW ZDEGRADOWANYCH PRZEZ GÓRNICTWO ODKRYWKOWE NA OBSZARZE PÓŁNOCNEGO PODLASIA

STRESZCZENIE: Artykuł dotyczy rekultywacji i rewitalizacji terenów pogórniczych w górnictwie odkrywkowym. W artykule opisano rekultywację wyrobisk kruszyw żwirowo-piaskowych zlokalizowanych na obszarze północnego Podlasia. Podstawową kwestią w rekultywacji piaskowni jest wybór kierunku zagospodarowania, uwzględniający zarówno uwarunkowania przyrodnicze, jak i techniczno-ekonomiczne rekultywacji. Głównym celem artykułu jest przedstawienie znaczenia badań rekultywacyjnych oraz konieczności równoczesnego uwzględnienia przez różne dyscypliny przyrodniczych i kulturowych cech krajobrazów pokopalnianych z różnych punktów widzenia w celu uzyskania jak najlepszego planowania użytkowania krajobrazu dla takich obszarów.

SŁOWA KLUCZOWE: rekultywacja, górnictwo odkrywkowe, tereny pogórnicze

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