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THE METHODOLOGY OF ASSESSING THE VALUE OF A WATER RESERVOIR

1. Introduction

The pit lakes reclaimed in the water mode may be utilized in many different ways, e.g. as natural protected areas, economic, recreational, and retaining, or ones which combine several of these functions (multifunctional). All of the aforementioned forms of utilization of the terrain require specific conditions, for instance concerning the configuration of the shores, the depth of the reservoir itself or the management of the surroundings. Therefore, the type of use of the reservoir should be taken into consideration during reclamation planning. Certain forms of use require specific morphometric conditions; therefore pit lakes sometimes have limited usable functions. The method of use of the reservoir is a derivative of independent environmental conditions or possible corrections likely to be carried out as a part of the reclamation works. These constraints may have characteristics which determine the method of utilization of a pit lake. As an example one may use the shape of the reservoir's area or its spatial form which are the consequence of the deposit's geological structure and the method used during its exploitation. Finally, a pit created as a result of open-pit mining is usually characterised by a compact shape and significant depth. The method of utilization and the possibility of economic use of the pit lake will affect the value of the neighbouring terrain.

These features which affect the value of the water reservoirs and the surrounding terrain will be discussed further in the article, however the most important ones include:

— water quality and the resistance of the reservoir against degradation,
— the location of the lake in relation to a main road and the quality of the road,
— economic usefulness and recreational advantages.

The quality of the water is dependent on the original condition of the waters naturally flowing into the mining excavation and the degree of soil environment's transformation. In the case of rock susceptible to chemical decay, certain transformation may occur which result in a worsening of the quality of the water flowing into the final pit. The quality of water is

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also influenced by the method of the pit's flooding, possible use of external sources of feeding, such as mine waters coming from dewatering of other pits, or water coming from surface streams which are characterised by appropriate quality class.

After the pit flooding phase is over, conditions which decide about the possible qualitative transformation are formed. The reservoir could be a subject of degradation or it may gradually purify itself. This is mainly dependent on the hydromophological features of the reservoir as well as on the circulation and the pace of water exchange.

Three groups of factors determining the **susceptibility of lakes to degradation** may be distinguished. In order to obtain definite indicators determining the susceptibility of the lake to degradation it is obligatory to link three groups of elements together:

— the elements typical for the direct and indirect catchment of the reservoir – these are referred to as catchment factors,
— the elements describing the shape, size and structure of the lake are the morphometric factors,
— the water reserves and relations existing in the area which constitute for the hydrological factors.

The many factors determining the susceptibility of the reservoir to degradation include: average depth, the ratio between the lake's volumes, its shore length, the percentage of the waters' stratification, the ratio between the active bottom area to the volume of the epilimnion, the water exchange coefficient, Shindler coefficient and the catchment development type. The factors determining the susceptibility to degradation were broadly described in the article [1].

The location of the lake in relation to a main road and the quality of the road may influence the potential attractiveness of the reservoir. Good communication and advantageous locations in relation to human habitats may influence the reclaimed reservoir's value if it is of recreational character. Currently, more attention is paid to the considerable significance of such water reservoirs from ecological and social point of view and it is postulated to take these factors into account during reclamation of pits [2].

2. The directions of utilization of pits reclaimed in water mode

In post-mining terrain, forest reclamation has been dominated in previous years. It is estimated that about 10% of post-mining terrain was reclaimed for water use [3]. An increase of water reclamation is expected in the future. Nowadays, the water mode of reclamation with a recreational character is the most preferred by local communities. Due to the mass use of these objects by local communities, they have to be appropriately adapted in order to fulfil all safety requirements. However, such forms of utilization rarely provide economic benefits. Maintenance of the reservoir requires significant costs and often special protecting works. The recreational mode of reclamation is rarely preferred by mining enterprises due to the financial burdens.

Entrepreneurs therefore prefer agricultural or fish breeding modes of reclamation. The pits used as fish breeding usually do not require additional expenditures for special protection of the reservoirs or on the shaping of the slopes. Economic modes of utilization usually require relatively shallow and small reservoirs. The physical and chemical parameters of water may be a barrier in this case.

On naturally valuable terrain, particularly on the terrain with a low number of water reservoirs, the mining pits may have natural function as protected areas. These objects contribute to an increase of species biodiversity. It is noteworthy that within Poland's borders, numerous zones of species protection have already been established in the areas surrounding artificial lakes, including Natura 2000 areas, landscape parks or areas of protected landscape [4].

Open pits are rarely utilized as retaining or attenuation reservoirs. In order to allow them to fulfil this role, reservoirs have to be located in floodplains or in their direct neighbourhood. The morphology of the surroundings of the reservoir has to allow for the shaping of the object as a retaining structure and the bed and the banks of the reservoir need to have appropriate hydrogeological and geotechnical parameters. Due to the multitude of different requirements and the preferences of local communities for recreational utilization, the retaining mode is usually not even considered during the planning phase of the post-mining terrains reclamation. Meanwhile, the retaining and attenuation mode of use of the post-exploitation pits could bring the most economic benefits to the local community. These benefits could be only temporary, however invaluable in the case of a flood. Large pit lakes usually have a considerable retaining capacity allowing for cutting off the cumulative wave of the flood and therefore for protecting the terrains located further downstream from the reservoir. However, such possible utilization limits other forms of use of the post-mining reservoirs.

The multifunctional mode of utilization of the pit lake requires certain conditions to be fulfilled which are required by different forms of use of the lake. Fulfilling all of them is often not even possible due to existing natural conditions. Usually for the first few years after the flooding the newly formed reservoirs are not an attractive environment. During this time, the post-mining reservoirs are characterised by significant instability and susceptibility to all kinds of changes caused by external factors and the lack of internal stabilizing mechanisms. As a result of the successive development of water plants and organic sediments forming in the lower depths (increase of the eutrophication), the influence of external factors of abiotic factors decreases in favour of the increase of significance of internal biotic and trophic factors. This way the post-mining reservoir gains the features of a natural lake or a eutrophic pond. With time, the reservoirs created in former pits obtain functions typical for the given terrain, e.g. recreational. The pit lakes may also potentially perform other roles, like water reservoirs or fire protection reservoirs.

The entries of the **act about the protection of agricultural and forest areas** oblige the entrepreneur to conduct the reclamation works within 5 years from the end of industrial activity. Water reclamation of open-pit mining excavations is usually a long-term process. This is caused by the volume of the pits and – in the case of the rock-mass drainage – the negative balance of water reserves in the rock-mass. The time taken to bring back the original water table is often a multiple of 5 years.

From the point of view of a mining entrepreneur engaged in economic activity and aiming at rationalization of reclamation costs and the potential income from the sale of reclaimed grounds, the initial assessment of value needs to be conducted as early as at the reclamation planning phase. Regardless of passing the terrains to the local authorities, or selling to another entrepreneur, the preliminary assessment of the value of the reservoir and the surrounding terrains may be the basic information used for decision-making support regarding the method and mode of reclamation and the ownership transformation of the post-mining terrains in order to pass them to the legal successor.

3. The methodology of assessing the value of grounds under still waters

The methods of assessing the value of grounds under still waters found in the literature on the subject concern both natural ponds and lakes as well as reservoirs which have been created in an artificial way – anthropogenic lakes. Reservoirs located in areas of high natural value are particularly precious. Thanks to the appropriate reclamation and adaptation works along with the processes of natural plant succession with time, after the reservoir has been completed and filled, a gradual increase in water quality occurs. This has an effect on the attractiveness of the reservoirs as places for recreation and relaxation for the neighbouring inhabitants. The rules for assessing the value of grounds under waters are strictly connected with potential possibilities for the future use of water reservoirs. For the assessment of grounds under still waters, three different approaches are commonly used in property value assessment. Accordingly to the Regulations of the Ministry Council from 21st September 2004 regarding property value assessment and preparation of the estimation statement, during the valuation of a property, in order to determine its market value, one may use the comparative and income approach. When existing conditions do not allow for either of these, a mixed approach is used.

According to this assumption, one must determine whether the given water reservoir will be used as a part of an economic activity. Then, one should conduct a valuation with the use of the income method, and if such use of the reservoir is not planned, using the comparative method.

The value of still waters suitable for fish breeding (fish ponds) is most often determined by using the investment method and the technique of simple capitalization. Income is tied to the investment method due to the fact that the income from such real estate is determined exclusively based on the rent and cannot be identified with the income from an economic activity conducted at the valued property. Using the investment method – the simple capitalization technique – the value of the property is calculated as a product of constant stream of annual income (the rent) possible to obtain from the valued property and the capitalization coefficient, or the quotient of the constant stream of annual income and the capitalization rate [5].

$$W_d = D \cdot W_k \tag{1}$$

where:

W_d – the value of the property,
D – annual income,
W_k – capitalization coefficient.

The capitalization coefficient (W_k) is the period of return of the capital expenditure used for the acquisition of the property from the income gained from the given property, determined using the following formula:

$$W_k = \frac{C}{DON} \tag{2}$$

where:

C – transaction price,
DON – net operational income.

The amount of income (including rent) from a fishing object depends on its production possibilities (both fishing and recreational) and these are determined by the natural productivity of the waters. For this the preliminary assessment of the productivity a fishing classification is used. It divides lakes into particular fishing types [6]. The natural productivity of ponds is assessed using a range of bonitation methods. The most common of these methods include those developed by: Staff as well as Popowski and Zakaszewski [7].

Another method often used for assessing the value of a property is the comparative method. The most commonly used method of real estate value assessment uses a method of comparison in pairs with an adjustment of the mean value. The comparison in pair's method, as described by Polish law regulations, is a linear interpolation based on the extreme values of prices and property attributes in the comparison database. The method of adjusting to the mean price is based on an average price from the database and on the standard deviation of prices from that database [8].

The general formula which determines the value of a property with the use of method of comparison in pairs has been given with the help of formula (3).

$$W = CT + V_t + V_a \tag{3}$$

where:

W – the value of the property,

CT – transaction price obtained in the free market for a similar property,

V_t – correction of the transaction price resulting from the change of the prices level at the local market for similar properties, calculated as a product of monthly gain/loss of prices (B) determined based on the analysis of the market and time expressed in months which passed from the day of the transaction to the day of the valuation:

$$V_t = B\left[\frac{\text{PLN}}{\text{month}}\right]\cdot(tw - tt)[\text{month}] \tag{4}$$

V_a – correction of the transaction price resulting from the differences of the market prices of valuated and compared properties, calculated as a sum of differences of particular attributes (market features) of the property ($A_w i - A_p i$) which is assessed and compared, expressed in an amount through their multiplication by unit cost shares of the attributes (u) determined basing on the analysis of the local market:

$$V_a = \sum(A_w i - A_p i) \tag{5}$$

Another method classified as a comparative method is the adjustment of the mean price method, which is calculated using the following formula:

$$W = C_{sr} \cdot U_w \tag{6}$$

where:

W – the value of the property,

C_{sr} – the mean of transaction prices obtained in the free market for properties similar to the assessed property,

U_w – correcting coefficient, calculated as weighted mean (the weights being the percentage shares of the market features in the explanation of the variability of prices) from the price correcting coefficients (u_i) assigned to the particular market features.

$$u_i = u_{\min} i + \frac{\left(A_w i - A_{\min} i\right)}{\left(A_{\max} i - A_{\min} i\right)} \cdot \left(u_{\max} - u_{\min}\right) \tag{7}$$

where:

$$u_{\min} = \frac{C_{\min}}{C_{sr}} \tag{8}$$

$$u_{\max} = \frac{C_{\max}}{C_{sr}} \tag{9}$$

$A_w\, i$, $A_{\min}\, i$, $A_{\max}\, i$ – values of the i-th attributes (market features) are respectively: the valued property, the property with minimal price from the database used for comparison, the property with maximal price from the database used for comparison.

The mixed approach to the assessment of property value is a compilation of comparative, income and cost-based approaches. In the mixed approach one uses the residual method or the grounds estimates coefficients method. Independently from the selected approach, the valuation of the water reservoir should be carried out using the analysis of water relations, the productivity and location of the ponds. In the comparative approach this will be the analysis of basic comparative features.

4. The assessment of value of the grounds under still waters

In order to conduct an accurate valuation of a water reservoir using the comparative method, one needs to determine the basic characteristics which may be significant to the value of the discussed property. Grounds under still waters which used to be mining terrains are relatively rare in the market circulation. The features which can have an influence on the value of natural and artificial water reservoirs have been presented in Table 1. For the mentioned features a scale has been proposed in order to estimate the value of grounds under still waters.

TABLE 1

The most often used scales for assessment of grounds under waters [9]

No. of the feature	Determination of the market feature	Assessment
1	Water quality and the trophic condition of the reservoir	– very high, – high, – low
2	Catchment characteristics	– very advantageous, – advantageous, – average, – disadvantageous
3	Resistance of the reservoir against the catchment's influence	– very resistant, – averagely resistant, – lowly resistant, – not resistant

TABLE 1 cont.

4	Location of the lake in relation to a main road	– very good, – good, – average, – weak, – very weak, – bad
5	Quality of the road	– very good, – good, – average, – low
6	Economic usefulness	– very high, – high, – average, – low, – very low
7	Recreational value	– very good, – good, – satisfactory, – low

When determining market features, one should be guided by the following assumptions.

— In reference to the 1st feature – the water quality and the trophic condition of the reservoir – one should use an individual limnologic system of classification of lakes adjusted to their ecological properties and susceptibility to degradation. This system links the trophic condition (fertility condition) of the lakes with the condition of their development. In general, we assume that a very high quality of water is typical for lakes with clean water of oligotrophic type. High quality water is typical for lakes of a clean water eutrophic type. Low quality of water is typical for lakes of a brown water of distrophic type.

— In reference to the 2nd feature – the catchment characteristics – one should consider the degree of influence of the catchment on the lake. This degree is dependent on:
  - lakeness coefficient,
  - the lake's balance type,
  - average inclination of the catchment,
  - the ground's permeability,
  - the degree of development of the catchment's area directly surrounding the lake.

— In reference to the 3rd feature – the resistance of the lake against the catchment's influence – one should take the following elements into account:
  - the average depth of the lake,
  - the rate of quotient of the lake's volume and its shore length,
  - the rate of quotient of the bottom located within the range of the epilimnion and the volume of the epilimnion,
  - Schindler's coefficient,
  - average annual intensity of the water exchange.

— In reference to the 6th feature – economic usefulness – the most valuable objects include the European white fish lakes (very high) and then: bream (high), zander (average), tench and pike (low) and crucian (very low).

— In reference to the 7th feature – the recreational value – the assessment of this feature is influenced by:
  - the forms of development of the direct catchment of the lake,
  - landscape value (the shape and development of the shore line, the number of islands, peninsulas, the lake's surroundings, the configuration of the shore and its inclination in relation to the water surface),
  - the possibility of tourism and walking recreation in the vicinity of the lake,
  - the possibility of sunbathing and bathing,
  - the possibility of fishing and underground hunting,
  - the possibility of practicing water sports and sailing [9].

5. The sales transactions of water reservoirs

The operations related to the acquisition and sales of water reservoirs are rare. However, in the last few years several transactions of this type have been conducted. For the purpose of this publication, several of these transactions which have taken place over the last two years have been presented. The data presents the accounting price, the transaction price, the area of particular water reservoirs, their location and a brief description of the given property (Tab. 2).

TABLE 2

The specification of chosen transaction concerning the grounds under waters (reclaimed post-mining terrains)

No.	Municipality	Area, [ha]	Transaction price, [thousand PLN]	Unit price, [thousand PLN / ha]	Description of the property
1	Grębów	3.84	275	71.615	reclaimed terrains of a former open-pit sulphur mine prepared for a recreational facility
2	Radłów	9.73	440	45.221	post-mining terrain of a gravel pit (mining ceased in the 90s)
3	Mietków	10.46	910	86.998	water reservoir in a pit where natural aggregates where mined, developed for recreational use
4	Wierzchosławice	5.97	350	58.626	post-mining terrain of a gravel pit from the 80s, good communication accessibility
5	Brzostek	14.35	556	38.746	two water reservoirs (3 and 11 ha of water area) created as a result of natural aggregates mining
6	Daleszyce	5.22	145	27.778	artificial reservoir created from sand mining, located in the surroundings of forest grounds
7	Brzyska	8.46	280	33.097	flooded former sand and gravel mine, developed for recreational use
8	Zdzieszowice	16.18	690	42.645	water reservoir (ca. 12 ha of water surface) together with surroundings of undecorated green fields (former limestone mine)
9	Ludwin	6.38	420	65.830	reclaimed terrains of a former open-pit mine prepared for a recreational facility

As one may conclude from the data presented in Table 2, the area of the water reservoir is not the only factor determining the price of a given property. The correlation between the area and the transaction price is 69%. Based on this fact one may conclude that factors which are not related to price are an important factor when value of a given water reservoir is assessed.

6. Summary and final conclusions

The final forms created as a result of open-pit mining activity can be reclaimed below the level of the original groundwater table in water mode. Such a mode of reclamation allows for the utilization of the pits as natural protected areas, recreational facilities, objects viable for economic activity, as retaining or multifunctional reservoirs.

The preliminary valuation of a post-mining reservoir conducted during the phase of its design allows for the rationalization of the costs for the preparation of the reservoir for its future use, both necessary reclamation costs, but also for maximization of the value of the reservoir intended for future sale. At this stage it is necessary to correctly assess the final condition of the water reservoir in the range of both the lake's and its surroundings' physiographic features.

In the methodology of assessment of value of the grounds located under still waters two approaches are dominant: the income approach and the comparative approach. In the case of reservoirs which can be used for future economic activity, the income method is used. Its purpose is to estimate future income from the economic activity conducted on the property. In the case of reservoirs which will not be used for economic purposes, the comparative method is used. This method is based on the assessment of the physical features of the reservoir and its surroundings. The most commonly used method of real estate value assessment uses the comparison in pairs method, and the adjustment of the mean value method. For the assessment of the value of grounds under waters one may also use the mixed method. The mixed approach to the assessment of the property value is a compilation of comparative, income and cost-based approaches. In the mixed approach one uses the residual method or the grounds estimates coefficients method.

When analysing the transaction price of the acquisition and sales of water reservoirs used for economic activity, one may state that their price is dependent on many factors, both related to their accessibility and their location. It is noteworthy that relatively high unit prices are obtained for reservoirs which are relatively small and which were created as a result of natural aggregates mining. In the case of larger water reservoirs, the obtained transaction prices are higher, though the unit prices are much lower. This is related to the rocky character of the ground which is an obstacle in the economic use of the reservoir or in its adaptation or shaping for the use as a recreational object.

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