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SHAPING THE WATER CONDITIONS IN THE POST-MINING AREAS (A CASE-STUDY OF BROWN COAL MINE „ADAMÓW")

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The article presents the issues of shaping the water conditions in the mining areas given the example of Brown Coal Mine "Adamów". At the stage of the exploitation of deposit by opencast mining, the water conditions in the mining areas are transformed, which is associated with the need to adapt their functions to the needs of the mining and energy sectors. These changes relate to the deep dehydration of aquifer horizons, transformation of hydrographic network (removal of watercourses, reconstruction of the riverbeds, construction of drainage canals) and, consequently, changes in the water cycle. After the exploitation, the reconstruction of water resources becomes an essential condition to achieving the equilibrium of these areas. The concept of formation of water conditions in the post-mining areas of KWB (Brown Coal Mine) "Adamów" presented in the study, takes into account the environmental aspect of the functioning of the water management (shaping of landscape water retention through the construction of water reservoirs, limitation of water discharges from the drainage to the network of surface water and retention within the catchment area) as well as its social dimension (development of recreational-holiday functions).

Keywords: post- mining areas, water conditions, water reclamation

1. INTRODUCTION

The over forty years of the intensive exploitation process of lignite deposits in the Polish Lowland, constituting a priority against other environmental and social conditions, has forced the changes in the functioning of the natural environment. In particular, they concerned the deep dehydration of aquifer horizons, transformation of the terrain and vegetation, which are the key

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components that determine the formation of water conditions of the landscape. As a result, the surface water in mining areas form a complicated, multi-functional system that requires an integrated way of management, which takes into account the aspects of quantity and quality of water as a raw material for the power industry, but above all, as the most important factor necessary for the proper and sustainable functioning of the natural environment. The issue of water management endearing the issues outlined above will be discussed in this paper on the example of the mining areas of KWB "Adamów".

2. TRANSFORMATION OF WATER CONDITIONS IN MINING AREAS

The area remaining within the range of influence of KWB "Adamów", along with the currently exploited deposits Adamów and Koźmin, is located below the line of maximum glaciation of the Vistula River (Baltic) that separates the lake districts from the lowlands. It includes the mesoregion of Turku Plateau and Kolska Valley, which is a fragment formed during the Middle Poland glaciation of the South Greater Poland Lowland [5]. The total lack of natural surface water bodies is a characteristic feature of the old-glacier landscape formed during the older glaciation period. The deposits of Adamów and Koźmin are located in the catchment of the Kiełbaska river, Struga Janiszewska and Teleszyna, associated with the left-bank of the Warta river basin.

In the period preceding the exploitation of deposits and the functioning of "Adamów" power station, the Kiełbaska river's catchment covered the area of 287 km². Due to the water needs of the power station, Teleszyna River, after the creation of Canal Warta-Kiełbaska, was partially used as an artery for water transfer. Having connected the Warta-Kiełbaska system to Kiełbaska river, which is the basin of the upper Teleszyna, the area of Kiełbaska's catchment increased to 476 km², which is close to 66% [1]. During the exploitation of the opencast pit Adamów and Koźmin, the waterbed of the Kiełbaska will not be changed; only the eastern part of the catchment is under the influence of the cone of depression, causing depletion of its water resources. The planned Adamów reservoir, along with the supply canal (running from the water intake on the Central Kiełbaska), shall create its own catchment, contributing to a reduction in the catchment area of the Kiełbaska. Currently, the Kiełbaska's hydrological regime is the result of interactions performed by the economic functions as well as environmental conditions of the anthropogenically modified river basin. The main components, which regulate the flow rate of the Kiełbaska are as follows:

- water from the natural catchment of the Kiełbaska

- water from the catchment of the Upper Teleszyna (covering the area of 206.26 km^2)
- water pumped by a pumping station Miłkowice (in Ostrów Warcki) with Jeziorsko Reservoir (on the Warta)
- mine water from the Adamów and Koźmin open pit drainages
- abstractions of non-returnable water for the cooling system of "Adamów" Power Station
- discharges of the excess water not used in the technological system of “Adamów” Power Station.

The size of the individual components are variable and shape the average annual flow of 1.45 m^3 s-1, and the average annual runoff per unit is 3.56 dm^3 s-1 km^2 [11]. The reduction of the unit outflow (3.56 dm^3 s-1 km^2) in relation to its characteristic value for the period preceding the development of mining (4.3 dm^3 s-1 km^2), despite an increase in the annual flow rate, is related to the influence of the cone of depression, within which, after the beginning of exploitation, there are fragments of the catchment.

The Teleszyna as well as its catchment have been permanently transformed due to mining activities. Part of the Teleszyna’s riverbed in the Przykona-Zimotki region was liquidated by the excavations of the open pit Adamów. Currently, water reservoir with a maximum flood area of 123.2 ha was built.

Struga Janiszewska and its catchment, within the exploitation period, along the whole section, are in the impact zone of the open pits. On the stretch of 2.99 km, the riverbed was destroyed by external dumping ground, and its function was overtaken by, so-called, Passive Channel, which was built along the eastern edge of the pit. Struga Janiszewska in its upper course carries periodic water - after a heavy rainfall, which is related to the impact of the cone of depression of the open pits Adamów and Koźmin. Having finished the exploitation and the creation of reservoirs Adamów, Janiszew, Koźmin, Głowy, the initial catchment area of Struga Janiszewska (49.08 km^2) will be reduced by 23.08 km^2, and the catchments created around the reservoirs Janiszew and Koźmin will divide it into two parts.

The Length of the Kiełbaska II (right tributary of the Kiełbaska), during the exploitation of the northern part of open pit Koźmin (years 2014-2020) will be reduced (from 15.49 to 11.25 km) due to the elimination of the source section of the river. After the construction of the reservoir Koźmin Końcowy, the catchment of the Kiełbaska II with the current area of 12.69 km^2, will be reduced by 2.75 km^2 and will cover the area of 9.94 km^2 [9].

The change of the course and order of watersheds, their uncertain nature within the mining areas, changes of the catchment area and the consequent difficulties of balancing them, are all the results of these transformations within the hydrographic network.

The changes in structure of groundwater are associated with dewatering of the deposit and its overburden. Within the area of the exploited deposits Adamów and Koźmin there are two main aquifer levels associated with the overburden (quaternary superficial) and subcarbonic-cretaceous complex. The dehydration of the open pit "Koźmin" located in the vicinity of the open pit "Adamów" results in joint cones of depression in both analyzed aquifer complexes of those pits. Their sizes are constantly changing due to the displacing exploitation of the open pits, as well as hydro-meteorological conditions. Hence, the ranges of the cones of depression are given and analyzed within specified period of time and state.

The above characterized transformations within the surface water and groundwater are marked also in the structure of the water balance of the catchment with the increase of the revenue side, where apart from rainfall, one must take into account the amount of the mine water discharged into the hydrographic network and the volume of water transferred from the Warta. The side of outgoing water gets reduced, because the catchments, or parts of them, which are within the coverage of the cone of depression, with the transformed surface layers of soil and changed moisture relations are characterized by reduced evaporation.

The above given examples of transformations of surface and groundwater within the influence of KWB "Adamów", help to identify that the most important feature which characterizes water conditions in the areas of the opencast lignite mines is deepening of the deficit of water resources by:

- water transfers between the catchments
- discharges of mine water directly to the surface water network (without trying to bring it into cultivation) outside the mining area, which perpetuates the dehydration process and prolongs the stagnation of the cone of depression
- change (usually decrease) of the unit outflow
- changes in physical parameters of the water associated with the exploitation and open-circuit cooling
- reduction of retention as a result of the liquidation of small water courses, streams, ditches, wetlands, small mid-field reservoirs that store large amounts of water [3].

Limiting the quantity and quality of disposable water resources by mining activities, which adds up to a shortage of water, due to natural conditions (typical of Polish Lowlands) is the main problem of water management in mining areas.

3. THE RATIONAL DEVELOPMENT OF WATER CONDITIONS IN MINING AREAS

The rational shaping of water relations means the implementation of the basic principles of proper water management: maintaining, as long as possible and as much water as possible in the landscape, thus, minimizing an idle outflow from the catchment. The opportunities to develop appropriate landscape structure in the process of multi-direction reclamation of post-mining areas accelerate the return of a degraded environment to a new state of equilibrium. In areas of the opencast lignite mining, prerequisite for the pursuit of balance is the reconstruction of water resources. The fulfillment of this condition is possible through an alignment of the outflow, and this process is associated with the need for retention of significant amounts of water. The largest volume of retained water is achieved through the construction of large reservoirs and proper shaping of the landscape structure, which will support the retention capacity of water resources and contribute to the increase in effectiveness and efficiency of the regulatory system of evaporation from the soil for transpiration [6].

Within the mining area subjected to analysis KWB "Adamów" in the 90's, after the period of transformation of water conditions as a result and the effect of the priority mining activities, began the stage of rational development of water resources through the development of water retention of landscape.

Shaping the landscape water retention is associated with undertakings that lead to the construction of water reservoirs. Currently, the four water reservoirs Bogdałów, Przykona and Janiszew, and Koźmin are the new elements of the post-mining landscape. Until the end of exploitation in this area (by the year 2023) there are plans to build three other ones. Realization of the project to build water reservoirs will mean that, in the landscape, where previously there were no natural water reservoirs, the share of surface water bodies will increase to 1062.17 ha, and the amount of retained water in the reservoirs will exceeds 231 million m^3. The list of the created and planned reservoirs and their parameters is presented on Table 1.

We shall pay special attention to the fact that the newly created and designed water reservoirs are located in areas completely transformed by mining activities, where the original ecosystems characteristic for the area of bio- and geo-diversity, have been permanently degraded. Construction of the reservoir bowl is carried out only with the use of land heaps from the overburden opening subsequent mining fields and hollow ends, and is a form of reclamation of post-mining areas.

Table 1. Present and planned reservoirs in the Adamów brown-coal mining area.

Reservoir (name)	Comple-tion date	Area of reservoir min-max	Capacity min-max	Usable capacity	Perma-nent flood reserve	Losses to evapora-tion	Function	Location
Reservoirs created in the post-mining areas of KWB „Adamów"								
	year	ha	mln m^3	mln m^3	mln m^3	mln m^3		
Bogdałów	1994	9,5	0,6	un-known	un-known	un-known	initially fire-fighting, later recreational, natural	external dump open pit Bogdałów
Przykona	2004	242	5,9-7,2	bd	bd	bd	recreational, natural, firefighting	internal dump open pit Adamów
Janiszew	2008	56,39-59,57	3,5-4,05	0,55	0,119	0,161	recreational	internal dump open pit Koźmin
Koźmin	2012	106,0-108,5	5,50-6,1	0,54	0,217	0,293	natural	post-exploitation excavation.open pit Koźmin
Planned reservoirs								
Głowy	ca.2014	63,5-64,5	17,3-17,7	0,42	0,129	0,174	recreational	post-exploitation excavation open pit Koźmin
Koźmin-końcowy	ca.2020	115,2-116,1	33,4-34,1	0,66	0,232	0,313	natural	final excava-tion open pit Koźmin
Adamów	ca.2023	462,0-462,0	161,7	0,00	0,924	1,247	unknown	final excavation open pit Adamów

Source: Own study based on [9].

Therefore, the controversy on the building of water reservoirs, associated with their negative impact on the environment, is not, in this case, subject to discussion. Occupying the land under the reservoir, degradation of existing aquatic habitats, destruction of the soil profile, the movement of large quantities of land masses and transformations of the terrain are all the already made changes. Reservoirs, with the exception of the reservoirs Przykona and Koźmin Końcowy, are located outside riverbeds (so called side reservoirs) and are supplied by surface water through the tributary canals which enables the fulfillment of another essential condition, from the ecological point of view: continuity and integrity of watercourses.

Another element of rational development of new water relations in mining areas is an attempt to reduce discharges of water from the drainage to a network of surface water and its retention within the catchment. It can be achieved thanks to a developed and adopted system of filling newly created reservoirs. Reservoir Przykona, which has been functioning since 2004, was filled with groundwater from dehydration of open pit Adamów. Reservoirs Koźmin and Głowy will be filled with groundwater from deep drainage by wells from the deposit Koźmin. Reservoirs Koźmin Końcowy and Adamów Końcowy shall be created in post-exploitation excavation of deposits Koźmin and Adamów, at the end of exploitation. Reservoirs' bowl will be formed by slope excavation and their sills. Reservoirs will be filled with groundwater from drainage wells located on the edge of the pit (bowl). Along with filling up the cavities, the amount of infiltrating water from the reservoirs will increase and, concurrently, the amount of water pumped by wells will decrease. Both of these processes will extend the time of filling up the reservoirs, but, at the same time, they will affect the regression of the cone of depression and the reclamation of aquifers. During this period, reservoirs will go for surface water supply, the amount of which should compensate for the loss of infiltrating water into the cone of depression and evaporation [9].

After the completion of the filling up of the reservoirs, within their impacts new regime of the waters will be shaped. Water reservoirs shall combine quaternary aquifers with the subcarbon – cretaceous level. In the hydrographic network system, we can clearly observe the changes in the course of watersheds connected with the separation of the sub-catchments of existing and planned reservoirs (Fig.1).

Technical casing of watercourses and reservoirs, which involve distribution structures (weirs, sluices' shafts), intake structures (culverts, pipelines) and damming structures (monks, transfers), allow to conduct water management of the catchment and regulate water conditions within it (e.g. supplying the reservoirs, water abstraction from rivers, water transfers between reservoirs, emergency management of water during floods, irrigation, fish farming). Reservoirs are the local drainage base, which determines the relations

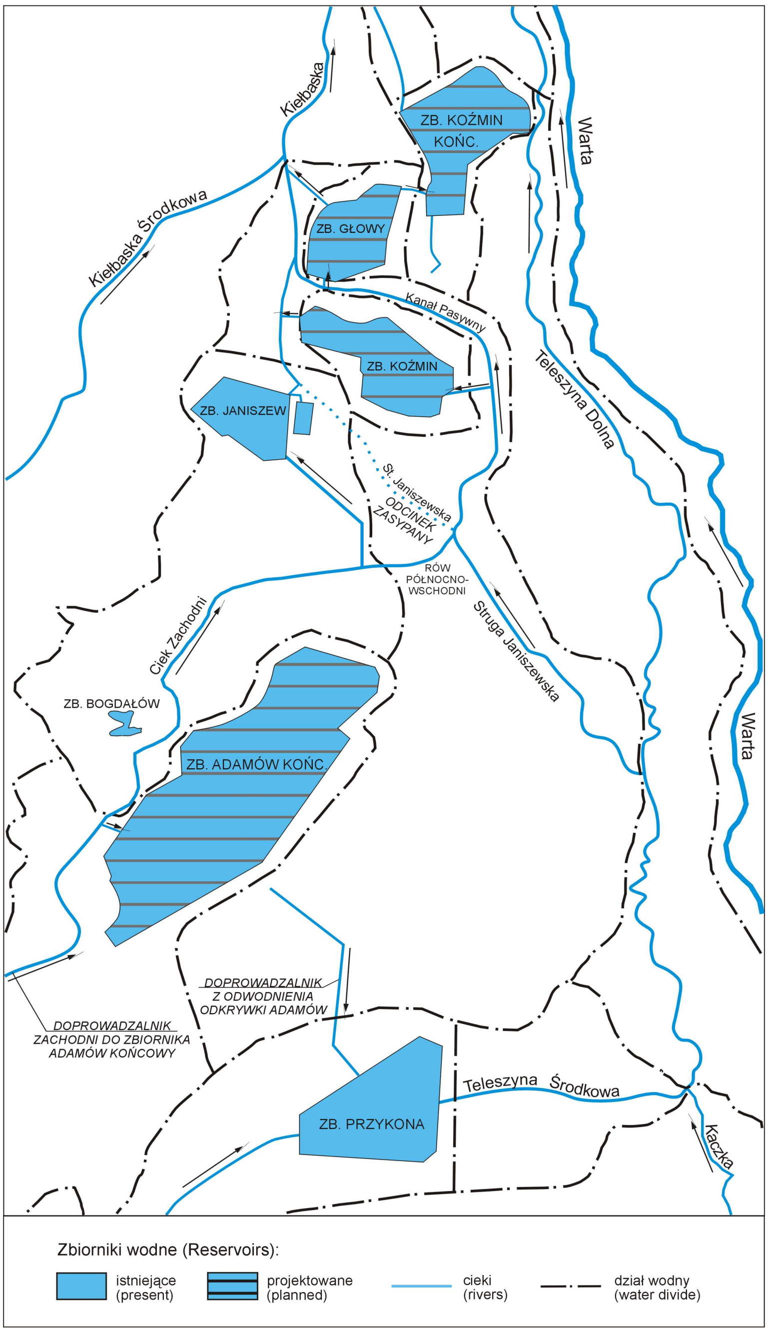

Fig. 1. Water conditions in the area of the Adamów Brown-Coal Mine on completion of exploitation (a conception). Source: [3] own study based on [9].

of the regime of surface and groundwater with the exploitation regime of reservoirs [12].

Reservoirs covering the extensive excavation, due to the water infiltration in the surrounding areas, will support the process of reconstruction of aquifers, and later, will contribute to the stabilization of the depth of the groundwater table and to the increase of the land retention resources. Thanks to the possibility to control the outflow from the catchment, by regulating the amount of the height of damming streams, there is a favorable hydraulic system between the groundwater table and the water flowing in the watercourse, which inhibits undesirable outflow to the groundwater, which underwent retention during the winter half-year, most often abundant in water [8]. Moreover, carrying out the irrigation with adjustable outflow increases retention of soil and promotes more efficient use of rainfall by vegetation, reducing the outflow. The creation of multiple possibilities, within a year, of renewal of capillary and groundwater retention allows the elimination of water shortage of 150 - 200 mm per year [7]. Usable capacity of reservoirs will come to between 420 – 660.000 m³ which gives a total of 2.17 million m³ Taking into account the possibility of 20 cm over-damming during flood releases, one can get flood reserve of 1.62 million m³ (Table 1).

4. THE IMPORTANCE OF WATER RESERVOIRS IN THE SHAPING OF POST-MINING LANDSCAPE

The most spectacular result of the implementation of the above concept of water reclamation is to change the landscape structure in the vicinity of Turku. Lake-density at the level of 6.97%. will be a new feature, which distinguishes this area (within the mining area of Adamów-Koźmin covering the area of 152.2 km²). For comparison, the lake-density index for Poland is 0.9% and for the areas with the highest concentration of lakes (according to Choiński, 2005): Mazury Lake District 3.05%, Pomeranian Lake District 2.03%, Greater Poland - Kujawy Lake District 1.23%.

Enriching the landscape structure with water reservoirs with a total area of 1,062.17 ha has an impact on different aspects of the functioning of the landscape. The first one is the increase in volume of evaporation, and consequently the increase of amount of water brought to the troposphere. According to the research of Rzętała [12] in the case of anthropogenic Rybnik Reservoir, one estimates 100 % increase in evaporation compared to the original terrain evaporation (before the formation of the reservoir), which provides, based on the total surface of the reservoir (450 ha), about 6 hm³ of water yearly. On this basis, it can be estimated that as a result of evaporation from the surface of all of the reservoirs formed in the area of KWB Adamów, the amount of water in the troposphere within one year will increase by 10 - 15 hm^3 and this estimation will be very significant in the water balance of the area and the reconstruction of water conditions. The presence of water reservoirs is also associated with the change of the topo-climatic conditions. The changes relate mainly to the increase in average daily air temperature, alleviating extreme low air temperatures in winter and hot in summer, with a lengthening of the growing season, limiting the occurrence of thermal inversions, increase in humidity and rainfall, more frequent fog and mist formation as well as a slight increase in wind speeds [4]. According to Lewińska (after [4]), the climate effects of large water reservoirs with the surfaces of 300 - 400 ha, might be noticeable at a distance of 2-3 km from the coastal zone.

Anthropogenic water reservoirs, either as a result of reclamation activities or as a result of spontaneous processes, take up ecological functions. Reservoir Bogdałów is such an example. Around it, in the process of natural succession, the sequence of aquatic, rushes and scrub vegetation, typical for limnetic reservoirs, has developed. New landscape elements, created in the process of reclamation, become biotopes for species-rich biocenosis. Artificial island on the "Przykona" reservoir, is currently a nesting colony of 6 species of gulls (including the only one in Greater Poland blackface gulls) and 2 species of terns, which makes it one of a few in Poland and Europe, mixed, multiple-species refuge of gulls and terns [13]. Within the settlers of dirty water in Piorunowe (open pit Władysławów) and Pęcherzewo (open pit Adamów) filled mainly by mineral - organic matter, rich habitat for many species of flora and fauna were shaped, especially waterfowls and wetland birds. In terms of natural valorization they form valuable communities. In order to preserve biodiversity of formed habitats, it is proposed to take the legal form of protection of settlers in the form of ecological grounds. These examples allow us to conclude that formation of habitats, which, previously, did not exist in this area and those related to it increase in biodiversity, thus becoming the most spectacular landscapes effect associated with the construction of water reservoirs.

Water reservoirs, formed in old-glacial area devoid of lakes, which are filled with clear waters of the deep drainage**,** around which the area with high natural values is created, are of significant importance for the development of tourism and recreation. The development of tourist-leisure facilities favors the use of reservoirs for leisure purposes. In the vicinity of the "Przykona" reservoir, there is a scouts' base, three bridges, car parks, guarded bathing zone with a sandy beach, water equipment hire, a snack bar functioning during summer and a football pitch. About 30 hectares of land around the reservoir were allocated for building holiday resorts (400 recreational plots) and services related to tourism and recreation. The whole complex of recreational areas is equipped with the power grid, water supply, access road, parking lots and sewage system. During the next stage, volleyball, basketball and tennis courts, changing rooms, showers and the lighting system are to be built. Water reservoir and its comprehensive development contributed to the development of new, previously non-existent (due to the lack of natural conditions of the area) forms of tourism, mainly associated with water: canoeing, surfing and sailing. Development of the area around the reservoir offers excellent conditions for active recreation (swimming, fishing, team games, walking, jogging) and recreation (sunbathing, camping). Created as a result of the water reclamation reservoirs, it performs a variety of functions, but because of its location in the immediate vicinity of the city of Turku and at the back of the Łódź agglomeration, in a range of daily and weekend penetration, their recreational functions have had the most significant importance. Water reservoirs are currently one of the biggest tourist- recreational attractions of Turek district.

5. SUMMARY

There are two significant stages in the process of shaping of water conditions in the mining areas. The first is to convert water relations and adaptation of water management to the needs of the mining and energy sectors. Another one, which started in the last decade, is characterized by a rational and comprehensive development of water conditions. The complex approach takes into account the environmental aspect of functioning of water management (reclamation of water resources), but also its social dimension (development of the functions of tourist-recreational as well as leisure functions associated with water). The above outlined concept of shaping water conditions in the process of exploitation and after its completion, allows for modern water management in closed systems - river catchments and constructed reservoirs. These actions should then lead to an increase in the amount of water in the landscape, increase in the intensity of its circuit and thereby to produce a new balance in anthropogenic water systems.

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KSZTAŁTOWANIE STOSUNKÓW WODNYCH NA OBSZARACH GÓRNICZYCH (NA PRZYKŁADZIE KOPALNI WĘGLA BRUNATNEGO „ADAMÓW")

S t r e s z c z e n i e

Wody powierzchniowe i podziemne terenów górniczych tworzą skomplikowany wielofunkcyjny system, który wymaga zintegrowanego sposobu gospodarowania uwzględniającego aspekt wody jako zagrożenia dla eksploatacji złóż, wody jako surowca dla przemysłu energetycznego, a przede wszystkim, wody jako czynnika niezbędnego do prawidłowego i trwałego funkcjonowania środowiska przyrodniczego. W opracowaniu przedstawiono problematykę kształtowania stosunków wodnych

w obszarach górniczych na przykładzie Kopalni Węgla Brunatnego „Adamów". Na etapie eksploatacji złóż metodą odkrywkową stosunki wodne w obszarach górniczych ulegają przekształceniom związanym z koniecznością dostosowania ich funkcji do potrzeb górnictwa i energetyki. Zmiany te dotyczą głębokiego odwodnienia horyzontów wodonośnych, przekształceń sieci hydrograficznej (likwidacja cieków, przebudowa koryt, budowa kanałów odwadniających), przekształceń rzeźby terenu i szaty roślinnej, czyli podstawowych komponentów, które warunkują kształtowanie się stosunków wodnych krajobrazu. Po zakończeniu eksploatacji działania w zakresie gospodarki wodnej powinny prowadzić do zwiększenia ilości wody w krajobrazie, zwiększenia intensywności jej obiegu, a tym samym do wytworzenia nowej równowagi w antropogenicznych systemach wodnych. Koncepcja racjonalnego i kompleksowego kształtowania stosunków wodnych przedstawiona w opracowaniu, uwzględnia aspekt środowiskowy funkcjonowania gospodarki wodnej (kształtowanie retencji wodnej krajobrazu przez budowę zbiorników wodnych, ograniczenia zrzutów wód z odwodnienia do sieci wód powierzchniowych i zatrzymanie ich w obrębie zlewni) oraz jej wymiar społeczny (rozwój funkcji turystyczno- rekreacyjnych, wypoczynkowych związanych z wodą).