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ANALYSIS OF WATER MANAGEMENT OF THE MICHALICE RESERVOIR IN RELATION TO ITS FUNCTIONS

ANALIZA GOSPODARKI WODNEJ ZBIORNIKA MICHALICE W ASPEKCIE JEGO ZAŁOŻONYCH FUNKCJI

Abstract: This paper focuses on the example of the Michalice reservoir located on the Widawa River. Its main functions are decreasing of flood danger beneath the reservoir, an availability of stored water in the basin for agriculture purposes and electric energy production, a creation of conditions for recreational use. Current water administration was analyzed. Special attention was paid to the proper use of the reservoir, and the benefits of its existence: the eutrophication rates, the classification of water, fish living and bathing purposes. It was affirmed that, the reservoir decreases the flood danger below the basin but it creates limited possibilities for recreation and pisciculture. Improper water management generates a danger of overflow onto the terrains around the reservoir. A small hydroelectric power station and fish ladder do not accomplish their tasks. Suggestions on how an improved water administration on the Michalice reservoir can occur are given.

Keywords: water reservoirs, water management, the exploitation of the reservoir, water quality

The Michalice reservoir on the Widawa River, is one of nine small water basins located in the Opole province, (southern Poland) it has a range of functions. These functions include, water storage in periods when water flow velocity is greater than the demand, or alternatively, if it is insufficient to need, flood protection, electric energy production, fishing (non-industrial pisciculture) and other recreational purposes [1–2] and agricultural irrigation [3].

The exploitation of the storage reservoir affects water management of the catchment basin both, in quantitative and qualitative ways [4–7]. Despite these varying functions,

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the reservoir maintains its condition without any difficulties [8]. However, fairly often, the reservoir's functions may be disturbed by the inflow of pollution into it, and this therefore causes a decrease in the quality of water in it. A substantial danger for the water basins is eutrophication [9–16]. Considering the significant role of small retention objects in the water management of regions, it is crucial that water management is led properly .

Proper administration of stored water requires work on a range of issues, including regulation of the frequency of the reservoir outflow discharge, leading on the reservoir's water administration while in regular use or in a situation of flood danger, selecting suitable reliable and controlling flows, measuring of sluice appliances. Furthermore, it is vital that the following is monitored: hydrology data in the catchment of the reservoir, issues concerned with the performance, safety, and stability of the ground barriers, the regulation method of water relations on the adjacent terrains, the water quality in the reservoir, spatial development around the reservoir together with, water-sewage management in the catchment, in order to preserve clear water in the water basin [5, 7, 17–19]. A significant factor in the optimum water basin utilization is the instruction of water administration, which is formulated by the Ordinance of the Polish Ministry of Environment, which oversee a range of water management duties [20]. This instruction ought be done, and lodged with the relevant department for each reservoir. Only then, can the reservoir be used.

The aim of this work is to analyze water management of the small Michalice dam against its prescribed functions.

Methods and materials

The research included stocktaking work on the Michalice reservoir and its devices and exploitation conditions. Current technical condition and the way water administration of the reservoir is deployed were rated. The analysis of the outflows from the Michalice reservoir and the water tract position in the reservoir were carried out from May 2005 to April 2006. [21]. In the study, the findings of the water quality research in the Michalice reservoir were gathered from two sampling stations: on the height of the Michalice village [Station 1] and above the reservoir's dam [Station 2] (Fig. 1), for the water samples collected during spring – autumn 2005 period [22]. The eutrophication state of the Michalice reservoir was gathered by the Ordinance of the Polish Ministry of Environment on the 23rd December 2002, it concerned determination of water susceptible to nitrates pollution from the agriculture settlements [23]. The quality of water in the reservoir was determined by a comparison of points that have been examined with the set limit on quality of water, being that required for fish live in [24] and for the safe bathing purposes [25]. The propositions of appropriate water management of the Michalice reservoir were given.

The Michalice reservoir is located at the 70.232th river-km of the Widawa River (Right bank of the Odra River tributary), about 1.5 km to the north from the town of Namyslow (Fig. 1). The reservoir was open for use from 2001, it is the second reservoir on this river, aside from the Stradomia reservoir situated on the upper watercourse of the river.

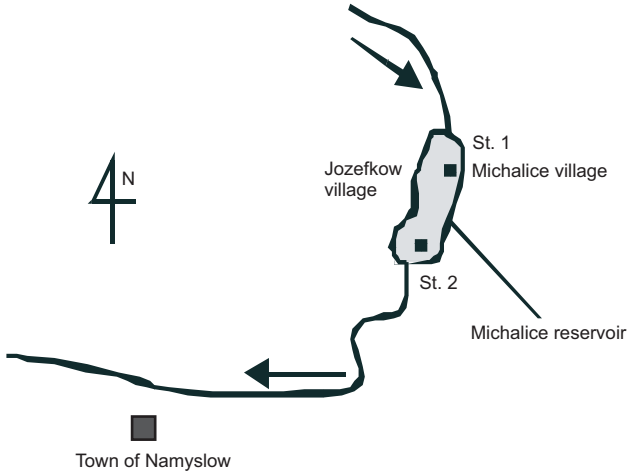

Fig. 1. The localization of the Michalice reservoir

At maximum crest backwater level (max crest width – 154, 20 m a.s.l.) the overall capacity of the reservoir is 1748195 mł with the total area – 95.7 ha. With regular backwater level (regular backwater level – 153, 50 m a.s.l.) the constant capacity of the reservoir accounts for 1191095 m^3 and the capacity available for flood control accounts for 557100 m^3, whereas its area amounts to – 92.98 ha. The average annual water outflow SSQ, in the Widawa River in a cross section of the reservoir is 2.04 $m^3 \cdot s^{-1}$, whereas the average mean water outflow is SNQ = 0.52 $m^3 \cdot s^{-1}$ [2, 26].

The dam on the Michalice reservoir is IV significance class. The overall length of the dam amounts to 455 m including discharging chutes. The cross-section of the dam has a trapezoidal shape (Fig. 2a). Located in the frontal dam of the reservoir are two constant surface spillways (Fig. 2b). These along with two bottom sluices, a small water power plant and fish channel constitute the main appliances in the dam body. Situated on the left side of the main part of the Michalice reservoir, there is the expansion tank,

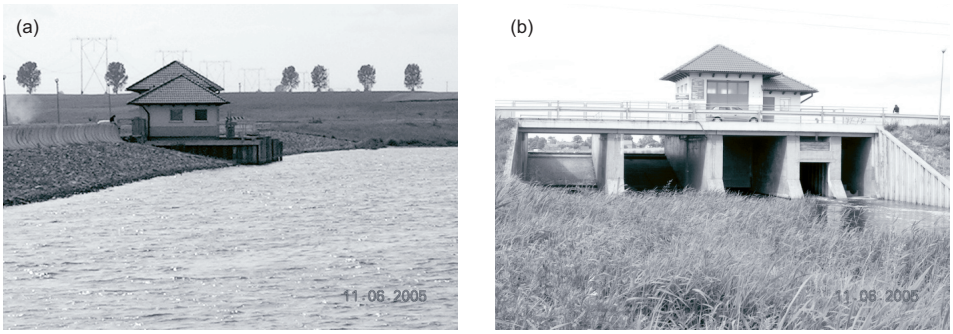

Fig. 2. The Michalice reservoir: (a) – The dam of the reservoir; (b) – The outflow from the reservoir together with the spillways, the exhaust from water power plant and fish ladder

which serves the purpose of collecting water for agriculture irrigation. The pumping stations for draining water are situated near the main part of the reservoir, in Jozefkow and Michalice

The reservoir's catchment area amounts to 509 km¸. Widawa is controlled in the reservoir area with the help of water gauges placed in the Michalice reservoir in the backwater zone, near the frontal dam and also, near the bridge in Namyslow. However, there is a lack of a water gauge patch directly under the reservoir. On the terrain of the reservoir, there is no meteorological station. The Michalice reservoir is under the administration of the Namyslow Community Office [1] and its main user is The Polish Angling Association.

The analysis of water management on the Michalice reservoir

Water management of the Michalice reservoir, can be divided into two operational states. The first is water administration in regular conditions of use and the second one, is flood danger state. The Regular conditions of water management on the reservoir occur when the following requirements are all met: the backwater level ordinate, does not exceed 153.50 m a.s.l., the inflow to the reservoir does not go beyond 3.0 $m^3 \cdot s^{-1}$, and a 'flood danger' emergency state is not announced. Additionally any damage to any part of the reservoir, has not threatened the reservoir's safety [2, 26]. During regular conditions of using the Michalice reservoir, controlled water management takes place, which means that the reservoirs fulfills agricultural and energy functions.

Water management in 'flood danger' state on the reservoir; occurs when at least one of the below conditions is met:

– the 'flood danger' emergency state was announced;

– the backwater level exceeds the normal backwater level ordinate, that is 153.60 m a.s.l.;

– the inflow to the reservoir went beyond 3.0 $m^3 \cdot s^{-1}$ [26].

The aim of the flood protection regulations are to effectively reduce flooding on the reservoir, this allows lightening spates in the valley of the Widawa River beneath the reservoir. Flood protection management is based on maintaining flood retention capacity which is filled up during an overflow.

The rules of water management can be established when the flood proceeding is divided into 3 stages:

a) the stage of filling the accidental or preparatory reserve;

b) the stage of filling the stable flood retention capacity;

c) the stage of recreating partially or entirely, filled flood reserve.

The period of the flood proceeding is carried out until the flood reserve is restored. Water administration on the Michalice reservoir in flood conditions is built on a fixed scheme of the outflow disposition [26]. According to Ciepielowski [27] this type of water management, while accumulating the wave crest, that is in the period when the inflows to the reservoir exceed allowed flow, the outflow equal to allowed flow is disposed. In the storage reservoir, the surplus of water over allowed Q is retained. Then, cutting of the wave crest is gained, however it happens only when the capacity of the

wave crest fits entirely into the storage reservoir. In a case, where the capacity of the wave crest exceeds the scale of the storage reservoir, a situation occurs where, overall filling of the reservoir may happen before the crest inflow arrives, which precludes its reduction [27].

Hydrological monitoring

The information about the formation of the water tract position in the reservoir, is significant from the point of view of conduced water management on the reservoir. The Fig. 3 presents ordinate values of the Michalice reservoir's stored water tract from May 2005 to April 2006.

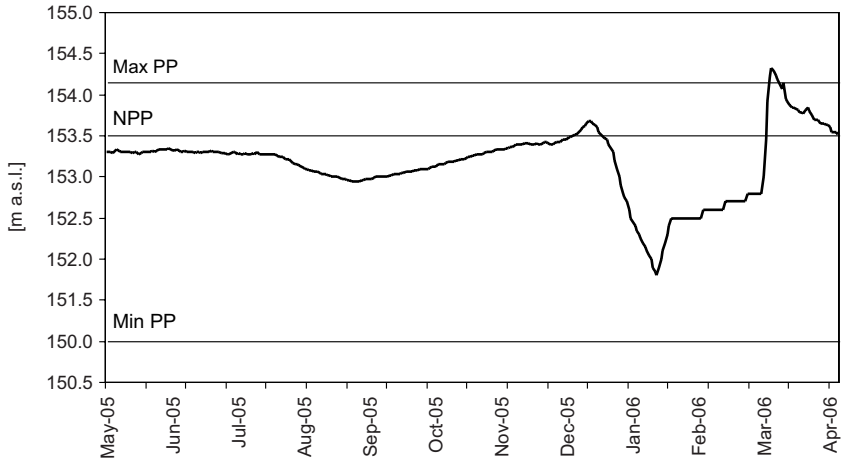

Fig. 3. The position of ordinate value of the water tract in the Michalice reservoir from May 2005 to April 2006

During the analyzed period the maximum level of backwater (Max. PP), which is specified in Water Management Instruction [26] on the level of 154.2 m a.s.l., was exceeded 13 cm. This situation occurred on the 28th March 2006 (Figs. 3, 4a). The described occurrence was due to the effect of melt water inflow to the reservoir. From the point of view of flood prevention, it is important to discharge prominently the reservoir, before the level of water in the Widawa River rises, this allows receiving and reducing of the spate wave. Otherwise, the inundation of the terrains beneath the reservoir's dam (town of Namyslow), Fig. 4a, as well as the undercut of terrains in the direct neighborhood of the reservoir will occur (Fig. 4b). In the analyzed period the minimum level of backwater (Min PP) which amounts to 151.00 m a.s.l. was not met. The ordinate value of regular backwater level (NPP) in the Michalice reservoir, which amounts to 153.50 m a.s.l., was exceeded only for 54 days during the research time (Fig. 3). During the remaining time, the water management was conduced under normal water level, accepted in Instruction [26].

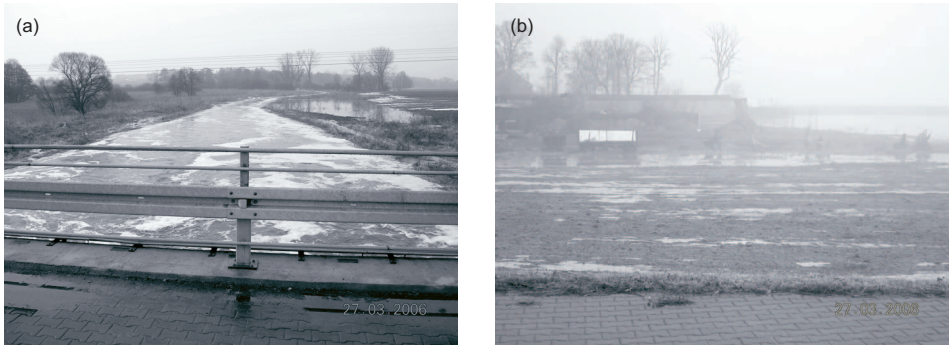

Fig. 4. (a) – The outflow from the Michalice reservoir on the Widawa River in March 2006; (b) – The undercut around the main part of the reservoir

The time of water retention in the reservoir

The time of water retention, which means the time it takes to exchange the reservoir's water overall, plays an important role in creating the reservoir's environment. It not only determines the hydrological system of the reservoir, but also together with intensity of water meddling, determines the matter circulation in the reservoir and what is more, it is a factor, which influences trophy state and water quality in the reservoirs [15, 28–29]. The retention time in the Michalice reservoir based on relation between water capacity outflowing from the reservoir to the capacity of the reservoir in the relevant period, was rated. In Fig. 5, the outflow from the reservoir from May 2005 to April 2006 and the water retention time are given.

The water outflow from the Michalice reservoir, in the period from May 2005 to April 2006, was quite stable. The average outflow amplification amounted to

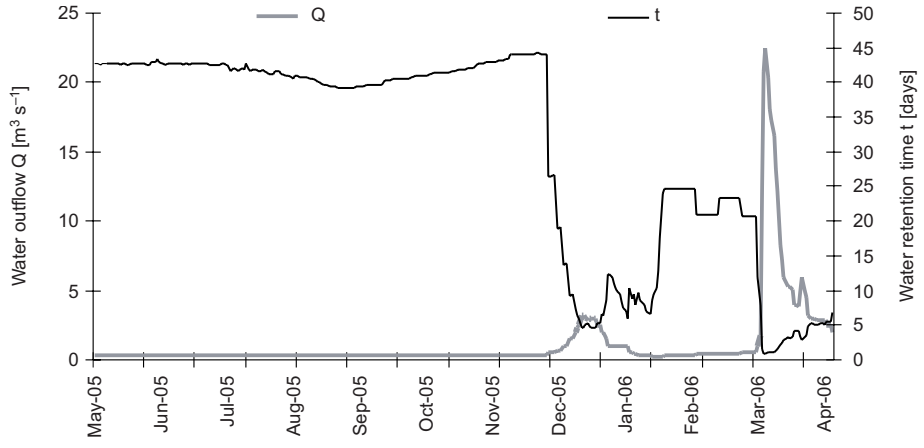

Fig. 5. Changeability of water outflow and water retention time in the Michalice reservoir during the period from May 2005 to April 2006

1.156 $m^3 \cdot s^{-1}$, and it was lower than water flow in the dam's cross – section of the Michalice reservoir [26], for the last 45 years, including 1997, when the flow amounted to 2.04 $m^3 \cdot s^{-1}$. The average time of water retention during this period amounted to 30.6 of day. During springtime of 2006 during March and April, the reservoir began to receive melt water. The effect of that, was a considerable decrease of the average twenty-four hours time of the retention, which amounted to about one day, an increase of an average daily outflow to 22.5 $m^3 \cdot s^{-1}$ on March 28, 2006,which exceeded the allowable flow value Q = 18.69 $m^3 \cdot s^{-1}$ given in Instruction [2, 26]. During summertime 2005, the lowest rate of outflows from the reservoir were registered (0.3 $m^3 \cdot s^{-1}$), and at the same time, vastly higher values of the average water retention time – 43.4 of day were noticed. During the reservoir's exploitation, the cast from the reservoir should be at least equal to unassailable flow Q = 0.26 $m^3 \cdot s^{-1}$. The average value of water capacity in the reservoir in the analyzed period amounted to 1.041 mln m^3 and the amplitude of water table variations in the reservoir was about 2.53 m.

Small water power plant

The small water power plant located in the frontal dam of the Michalice reservoir (Fig. 2b) is characterized by the following technical parameters: power output – N = 62.4 kW, the parameter of Q = 2.04 $m^3 \cdot s^{-1}$, the light of the upper channel B = 4.0 m. An assumed annual average production of electric energy 464809 kWh, the turbine type: Francis turbine with a vertical axis, rotor diameter D = 1230 mm [2], is currently out of order due to the turbine's failure.

Fish ladder

A properly working fish ladder plays an important role, it enables fish migration, so fish can live in a mixed environment. It enables migration of fish up the river across the reservoir's dam. The existing fish ladder on the Michalice reservoir which is a chamber type (Fig. 2b) with light b = 2.0 m, flow velocity 0.19 $m^3 \cdot s^{-1}$ and eight, 2 meters long chambers with ferroconcentrate baffles does not function properly. The filed investigations on the Michalice fish ladder, carried out on it in the years 2006–2008, show that it is inefficient. The main reasons for this are too little water depth on the entrance to the fish ladder from the lower water and in the chambers. Secondly, too low feeding or even perhaps the feeding deficit. It is very important matter, during fish migrations and spawning time [30]. Water management on the Michalice reservoir should provide for the vital requirement of a properly functioning fish ladder in the water, especially as shown in similar periods as those mentioned above.

The water quality in the reservoir

Table 1 presents the outcomes of chosen physico-chemical indicators of the Michalice reservoir water from 2005 [22].

The pH-value of water sampled in summer time from the reservoir, indicated the process of water alkalization – values within the confines of 8.8–8.9 (Table 1).

Table 1

The quality of stored water in Michalice reservoir in the year 2005

Sampling sites	Research periods	pH	Chlorophyll *a* [μg · dm^{-3}]	Concentration					
				NO_3^- [mg · dm^{-3}] Nitrates(V)	NO_2^- [mg · dm^{-3}] Nitrites(III)	NH_4^+ [mg · dm^{-3}] Ammonia	Total N [mg · dm^{-3}]	PO_4^{3-} [mg · dm^{-3}] Phosphates	Total P [mg · dm^{-3}]
Station 1 Waters of the Michalice reservoir	spring	—	87.4	7.75	0.144	0.588	3.49	< 0.050	0.162
	summer	8.8	48.1	< 0.50	< 0.046	0.66	—	< 0.050	0.260
	autumn	—	18.3	< 0.50	< 0.046	0.575	—	< 0.057	0.158
Station 2 Waters of the Michalice reservoir	spring	—	61.5	5.54	0.135	0.541	3.13	0.068	0.141
	summer	8.9	37.8	< 0.50	< 0.046	0.66	—	0.081	0.245
	autumn	—	20.2	< 0.50	< 0.046	0.66	—	< 0.074	0.212

The analysis shows that, in summer water temperature in the Michalice reservoir was 20.8–23.0 ^{o}C. In autumn water temperature in the reservoir was 12.9–14.2 ^{o}C. The dissolved oxygen contents in all analyzed periods in the reservoir's water were oxygenated properly (7.13–12.2 mg $O_2 \cdot dm^{-3}$). The highest level of nitrates(V) and nitrates(III) were observed in spring, while, in summer and autumn minute quantities of these elements were registered in the reservoir's waters. Higher ammonia concentration in the water was registered in summer [22].

The analyses carried out, in the year 2005, indicated high chlorophyll *a* concentration in the waters of the reservoir, in spring and summer time (87.4 μg $\cdot dm^{-3}$), Table 1. The extortionate presence of phytoplankton in algae form, which causes water bloom, is objectionable.

The analyses presented in Table 1 shows that, among other eutrophication indicators, the chlorophyll *a* concentration in waters of the reservoir in the spring and summer period helps indicate the eutrophical character of these waters. Either, a higher phosphorus or nitrogen concentration (Table 1) implies the eutrophication of water samplings taken from the reservoir body [23].

The analysis of water in the reservoir in terms of requirements for inland waters, that being a liveable environment for salmon and carp species living in normal conditions [regulation 2002a] showed that, the water temperature (for carp species) and ammonia nitrogen N-NH_4^+, which does not exceed a value of 0.78 mg N-$NH_4^+ \cdot dm^{-3}$, comply with these requirements. The most adverse conditions for fish living were nitrates(III), which exceeded the required [24] value of 0.01 mg $NO_2^{\dot{Z}} \cdot dm^{-3}$ for salmon species, and 0.03 mg $NO_2^{\dot{Z}} \cdot dm^{-3}$ for carp species, phosphorus (summer) and water temperature (Table 1) for salmon species.

The reservoir should also be used for recreation purposes [2, 26]. However, it can be noted the quality of water in the reservoir at the height of Michalice village (Fig. 1, Station 1), on account of a slightly raised phosphorus concentration, does not comply with the requirements on water, which is used in lidos in inland waters [25]. The too excessive contamination of the reservoir may have been contributed also by too large loads of anglers' baits. Equally important is proper water and sewage management led in the catchment of the reservoir, as well as, on agricultural holdings and lodges that are located around the reservoir.

The study carried out on the Michalice reservoir shows, that during the analyzed period, the reservoir was in the second stage of the utilization development. This stage usually lasts 2–10 years from the moment of tankage. The overall rise of the reservoir's fertility takes place, because the sediments are not fully formed and are from flooded soils along with decomposed greenery, which gives the water biogenic substances. During this period a mass expansion of some phytoplankton forms may occur [31].

Conclusions

As Mioduszewski and Los state [4] a large constriction in the use of the small retention reservoirs is that, these objects do not have a guaranteed constant availability of use by the professional services, which are able to operate the sluice devices in

a proper way. The Michalice reservoir, administrated by the Community Office in Namyslow, has been in use since year 2001 thus, it is relatively new reservoir. The devices condition does not arouse any objections. The observations confirm a periodical renovation of the devices (Fig. 2). Only the small water power plant and the fish ladder do not work as they were intended to [2]. The Small water power plant should be redesigned once more, to fulfill its purpose, as presented in the reservoir's project plan. Furthermore, the fish ladder should be converted because at present it does not accomplish its role.

The water management of the reservoir in regular backwater level periods, as well as, during flood water level periods should follow a set procedure in order to provide proper functioning and exploitation on the reservoir's devices and to prevent danger for people and the surrounding estate. So that the reservoir cannot negatively affect the adjacent terrains, as it had in March 2006 (Fig. 4).

The main danger for the Michalice reservoir is the quality of water condition. In the analyzed period large quantities of chlorophyll *a*, nitrogen and phosphorus were noticed. This shows the eutrophic character of water in the Michalice reservoir, it means the use of the reservoir for recreation is limited. The water bloom occurrence confirms this. In turn, the nitrates(III) concentration exceeded an acceptable limit for salmon and carp species, and phosphorus along with temperature levels for salmon species.

In order to lead optimum water management on the Michalice Reservoir, it is necessary to continue a hydrologic monitoring of water quality. An automatic hydro-met station should be installed in the catchment of the reservoir. A water gauge should be placed under the reservoir. The analysis of water quality should be carried out at least 3 times a year – at the beginning of the growing season (April/May), during the growing season (July, August), and after the end of growing season (October/November).

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ANALIZA GOSPODARKI WODNEJ ZBIORNIKA MICHALICE W ASPEKCIE JEGO ZAŁOŻONYCH FUNKCJI

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Abstrakt: Na przykładzie zbiornika Michalice na rzece Widawie, którego założonymi funkcjami są zmniejszenie zagrożenia powodziowego poniżej zbiornika, wykorzystanie zgromadzonej w zbiorniku wody dla rolnictwa i do produkcji energii elektrycznej, stworzenie warunków do wypoczynku i rekreacji, przeanalizowano aktualną gospodarkę wodną. W pracy wykonano analizę odpływów wody ze zbiornika do rzeki Widawy, poziomów wody w zbiorniku i jakości wody retencjonowanej w zbiorniku. Szczególną uwagę zwrócono na ważne, z punktu widzenia prawidłowego użytkowania zbiornika walory użytkowe wody: ocenę eutrofizacji wód zbiornika, klasyfikację wód do bytowania ryb i do kąpieli. Stwierdzono, że zbiornik zmniejsza zagrożenie powodziowe poniżej zbiornika i stwarza ograniczone możliwości dla rekreacji i hodowli ryb. Niewłaściwa gospodarka wodna na zbiorniku stwarza jednak zagrożenie podtopień terenów wokół czaszy zbiornika. Mała elektrownia wodna i przepławka dla ryb nie spełniają stawianych im zadań. W pracy podano propozycje prawidłowych zasad gospodarki wodnej na zbiorniku Michalice.

Słowa kluczowe: zbiorniki wodne, gospodarka wodna, eksploatacja zbiornika, jakość wody