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THE CONDITIONS FOR THE LOCATION OF SMALL WATER RETENTION RESERVOIRS IN ŚWIĘTOKRZYSKIE MOUNTAINS (POLAND)

Keywords: *water reservoir, small retention, Świętokrzyskie Mountains*

Introduction. Small retention covers the system of techniques aimed at improving hydrographic conditions in a catchment, which consists of the lengthening of the time and way of water and wastewater circulation (Kowalczak 2002). There are included natural as well as technical forms of water retention. The natural ones are: landscaping in the catchment (change in land utilization e.g. forestation, proper spatial arrangement and types of development forms), an increase in soil retention and reduction of erosion (proper slope shaping, agrotechnical measures, introducing durable protection vegetation, proper utilization of drainage systems), preservation and revitalization of hydrogenic habitats (swamps, moors and marshes). The technical forms of retention are basically limited to valleys and river beds. They include, most of all, water reservoirs of different sizes and purposes (ponds, field agricultural reservoirs, fire water reservoirs, oxbow lakes, moats, clay pits) and installations, which enable water level adjustment (weirs, gates, barrages) as well as flood polders, inter-dike areas, canal and trench system connecting the main river with oxbow lakes, properly functioning drainage systems.

As far as the availability of water resources is concerned, Świętokrzyskie Voivodeship is one of the poorest in the country (3.6%) (Suligowski et al., 2009). It is, therefore, indispensable to undertake the activities aiming at their increase, what would be profitable from the natural and economic points of view. Its result will be i.a. an increase in area humidity, the growth of groundwater level, the mitigation of extreme occurrences, including floods and droughts, or the reduction of their effects. Such a situation would favour the improvement of groundwater purity and the possibility of its utilization for agricultural melioration as well. An unquestionable effect would also be the significant development of tourism and recreation in the analyzed area.

The aim of the elaboration is to show the selected natural and anthropogenic conditions, which determine the location of small water reservoirs in Świętokrzyskie Mountains.

Water reservoirs in Świętokrzyskie Mountains – existing and planned. Świętokrzyskie Mountains are a physiographic mesoregion of the area of 1680 km^2 drained by Nida, Kamienna, Czarna and Koprzywianka and partly by Opatówka (Fig.1). The analyzed area is entirely located in Świętokrzyskie Voivodeship, within 29 municipalities.

The natural environment of Świętokrzyskie Mountains did not favour the emergence of bigger, natural reservoirs (>1 ha), whereas it is suitable for the location of artificial hydrographic objects. It is a result of favourable conditions of climatic water balance as well as convenient lithological and morphological river beds. An additional argument for building water reservoirs, especially at forest boundaries, including the preserved ones, is here the centrifugal layout of river network, whose waters in the upper parts are characterized by high purity and its quality deteriorates downstream. It is nowadays that Świętokrzyskie Mountains are distinguishable against the voivodeship

with their bigger groundwater resources accumulated in reservoirs, and in the following years their further increase is planned.

The inventory of the objects within the scope of water retention reservoirs and pondages, done on the basis of the Small Water Retention Program for Świętokrzyskie Voivodeship (2006), based on the analysis of the issued water rights licenses for respective objects as well as the information gathered in each municipality indicated, that within Świętokrzyskie Mountains there are 17 small retention reservoirs (>1 ha) of the total area 798 ha and the capacity of 48 000 m^3, and 14 pondages of the total area of 31 ha and the capacity of 19 000 m^3. The greatest number of the existing reservoirs are located in Nida catchment (17) (Fig. 1). There are also here the largest objects (>10 ha): in Borków, Cedzyna, Suków-Piaskownia, Wilków, Umer and Kielce (Kielce reservoir). A few more has an area from 2 to 10 ha. In Kamienna catchment there are 6 water reservoirs (>1 ha), Czarna and Koprzywianka catchments 4 in each.

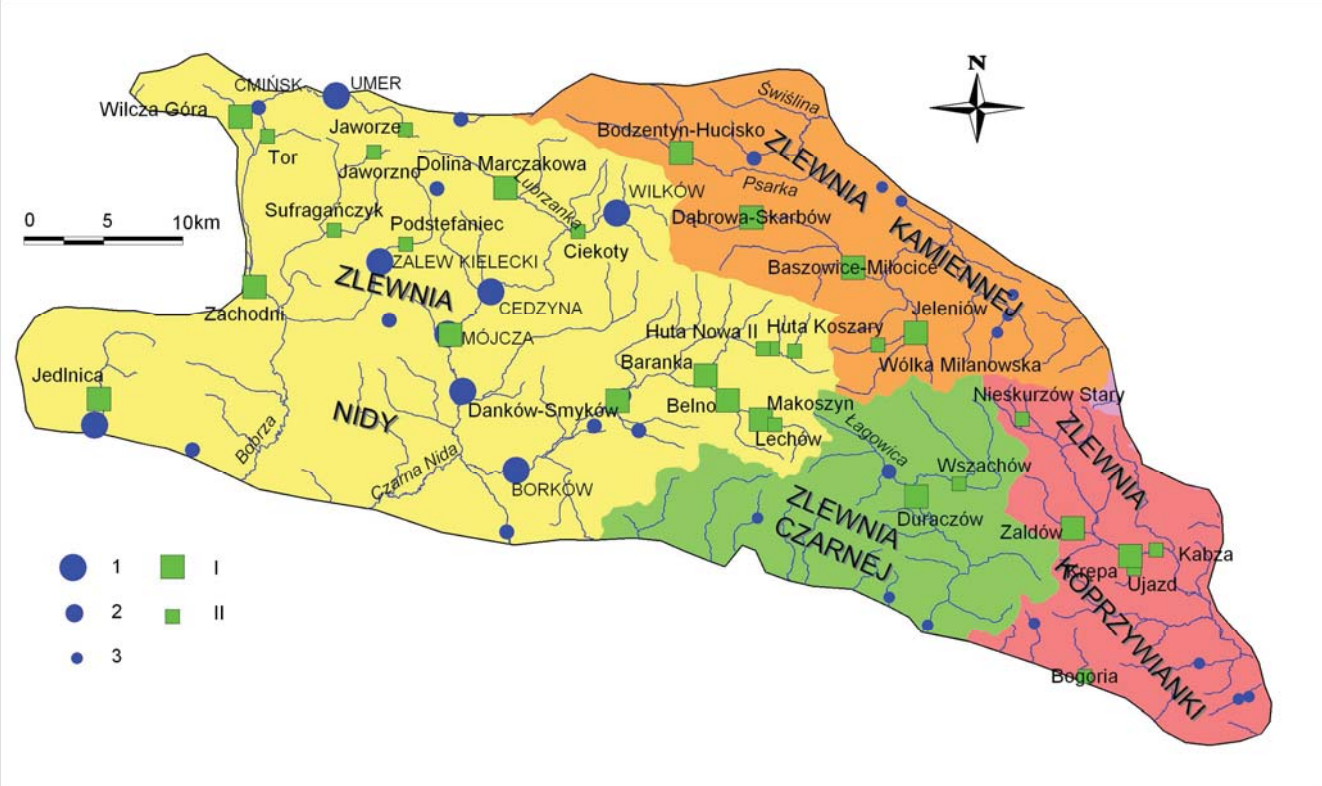

Fig. 1. **Existing water reservoirs (1 – above 10 ha, 2 – from 2 to 10 ha, 3 – below 2 ha) and planned (I – above 10 ha, II – below 10 ha) against Świętokrzyskie Mountains catchments.**

In Świętokrzyskie Mountains there are plans for creation (by 2020) of 32 water reservoirs of the area of at least 1 ha. Most of the discussed objects are designed for retention and recreation, although there are also planned reservoirs of complex functions such as: flood control, power engineering (MEW), angling.

Most of the objects are to be created in Nida catchment (19) and the least in Czarna Staszowska catchment – 2. Considering the dimensions a designed reservoir in Mójcza stands out (Lubrzanka catchment), whose area is supposed to be 130 ha and effective capacity over 3 mln m^3.

There have been proposed relative measures in the form of the ratios specifying total effective (W_{vu}) and flood capacities (W_{vp}) of the planned reservoirs in relation to the individual areas of the catchments (10^3 m^3 /km^2). The highest values of both ratios within Świętokrzyskie Mountains are characteristic of Kamienna catchment (W_{vu} = 11,8 and W_{vp} =4,6) (Fig. 2). The ratio for the total flood capacity W_{vp} in Kamienna catchment

is four times higher than a similar ratio in Nida catchment, which indicates greater planning possibilities and at the same time the need for flood water retention.

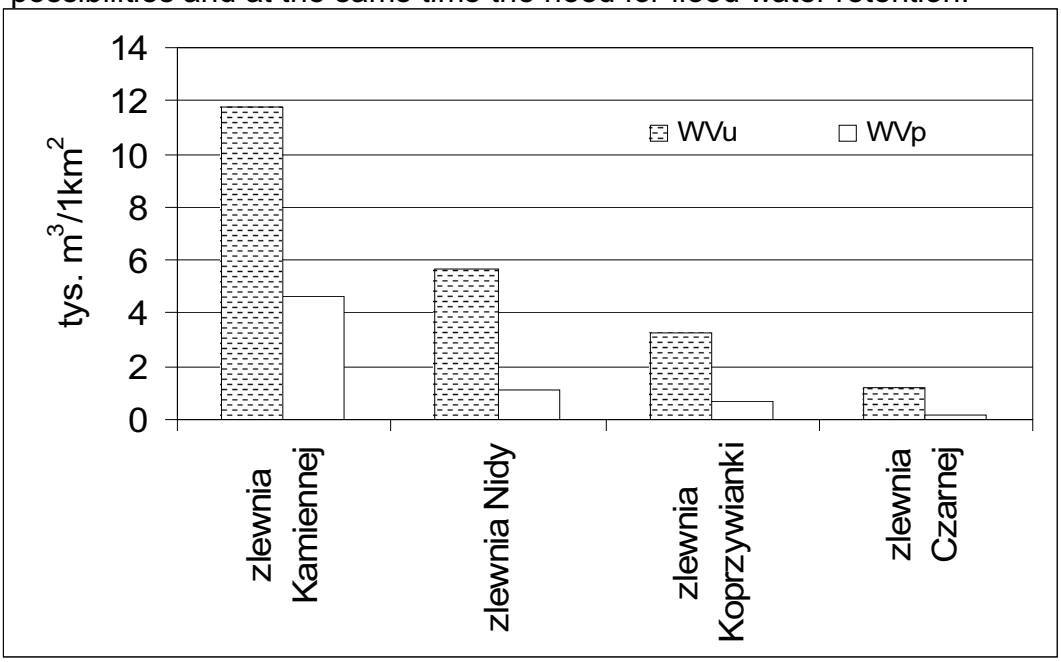

Fig. 2. **The ratios for the total effective (W_{vu}) and flood capacities (W_{vp}) of the planned water reservoirs in Świętokrzyskie Mountains catchments.**

The conditions of the location and functioning of the reservoirs. The location of small retention objects is connected with two groups of factors: natural and anthropogenic. The former group includes the lithological features of soil (including i.a. ground permeability and hydrogeological conditions), morphological features (i.a. slope inclination and river network density), components of climate (especially atmospheric supply and evaporation). Among the factors determined by human activity, there are utilization including the structure of permanent crops and land development components, which influence the circulation dynamics and quality of waters.

In the discussed area there are distinguished geological structures and formations, which belong to the paleozoic stem group and form anticlines and synclines. The result is the occurrence of a number of inselberg ranges, separated by broad and flat plains, filled with quaternary formations. In the areas, where weakly permeable layers are comparatively shallow in the ground whereas the surface of groundwater crosses the ground surface, and in the places where groundwater drainage is difficult, there are areas predisposed to water accumulation and retention. They are formed into numerous wetlands and swamps.

The permeability of the ground in the discussed area determined on the basis of lithological features of surface formations, indicates the predominance of weak or medium permeability. The slopes in the eastern part of Świętokrzyskie Mountains are covered largely with loess patches, which are characterized by differentiated permeability. Considerable terrain slopes in Świętokrzyskie Mountains are reflected by the slopes and large density of streams. In the middle (uppermost) part of the area their source segments are parallel, not side charged, and the network system is forked. In many cases their slopes exceed even 100 per mils, reaching an average of over 10, what classifies it as a typical upland river. At the feet of the heights the watercourses flow in broad valleys with flat channeled bottoms. These morphometric features of the valleys (predominantly in pre-gorge segments) favour water retention in artificial

reservoirs. At long sections the river valleys in Koprzywianka catchment are deep (up to 60 m) and has been formed in the loess cover.

The areas practically waterless (in Old Paleozoic formations) of the efficiency of 0-2 m^3/h cover 51% of Świętokrzyskie Mountains area (Fig. 3). These ares are also characterized by particularly fast groundwater flow, especially in storm precipitation periods, what causes water privation in the area. This is the reason for the necessity of undertaking the activities, which on the one hand should reduce the effects of a flood, and on the other hand fill the needs for fish ponds and green vegetation irrigation. There is planned the location of a few water reservoirs in the region for this purpose.

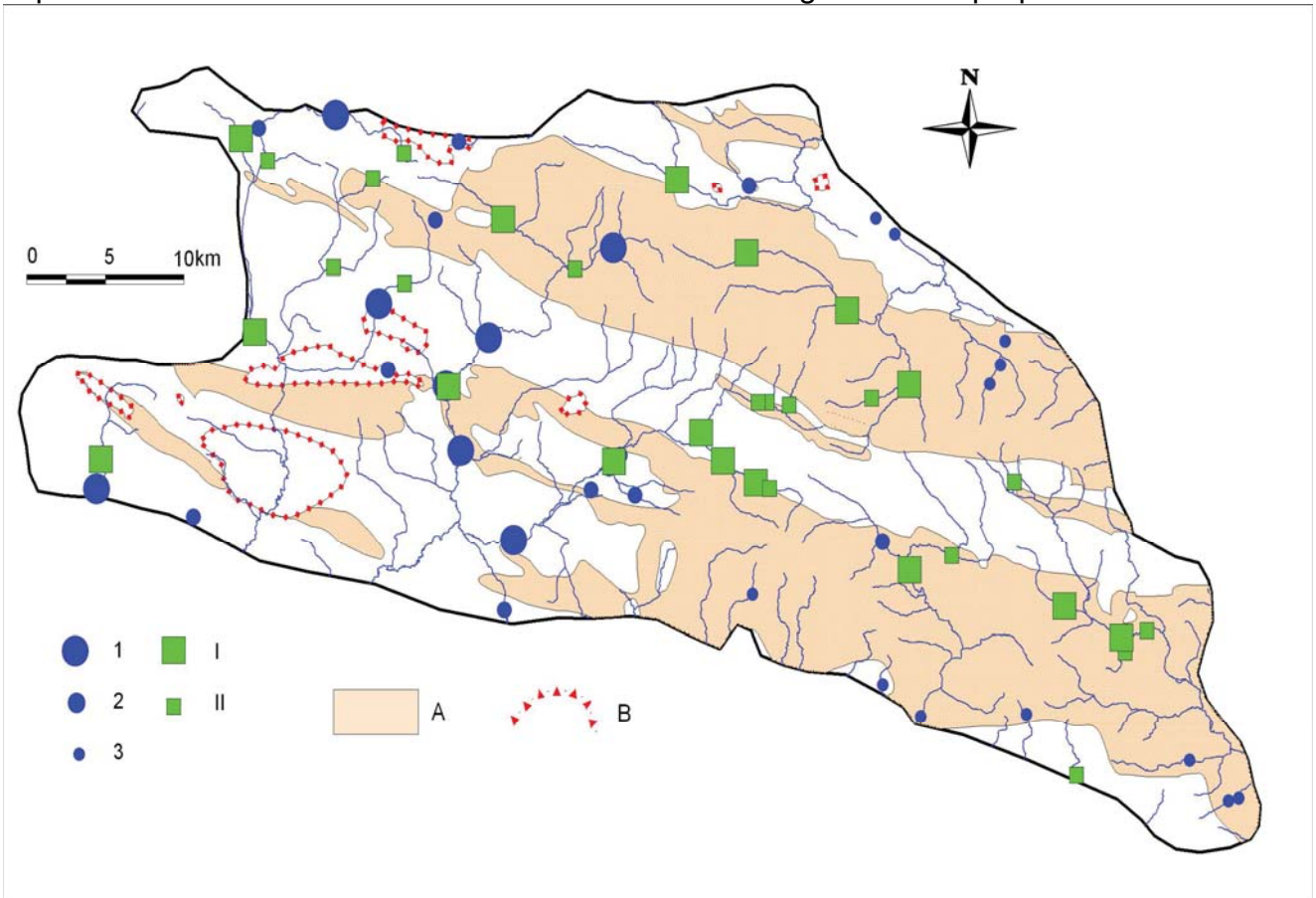

Fig. 3. **Existing water reservoirs (1 – above 10 ha, 2 – from 2 to 10 ha, 3 – below 2 ha) and planned (I – above 10 ha, II – below 10 ha) against the areas of potential efficiency of a typical well-hole from 0 to 2 m^3/h (A) and the ranges of depression cones (B).**

In the remaining area, the hydrogeological conditions are more differentiated, the efficiency is from 2 to 30, and locally up to 120 m^3/h, mainly within the quternary multiaquifer formation. The lack in abundance of underground water reservoirs and a very variable water efficiency is the reason for the need to seek the solutions, taking into account different methods of retention.

An essential component, besides morphological and hydrogeological conditions, indicating the possibility of the location of small retention objects are climatic conditions, especially the quantity of feeding in the form of precipitation and the loss in evaporation.

In the distribution of annual total precipitation in Świętokrzyskie Mountains clear relation between amount of precipitation and hypsometry can be observed. The highest precipitation is recorded at the uppermost weather station – Święty Krzyż, with the mean annual precipitation in the years 1961-1990 of 822 mm. The stations on the south-eastern side of the Main Range (Łysogóry) located in its “shade”, in relation to the

inflow of rain-bearing masses of air, receive far less of total precipitation, the example here is Daleszyce meteorological station (589 mm) (Suligowski et al. 2009). At the other precipitation stations in the region total annual precipitation is within 650-800 mm. In the annual course of precipitation there definitely prevail summer season precipitation (V-X). They are about 65% of total annual. Maximum precipitation occurs at most stations in July.

A characteristic feature in the process of precipitation in Świętokrzyskie Mountains is a high rate of participation in the solid form. It is over 2% higher in comparison with the adjacent areas. The individuality of the pattern of precipitation in Świętokrzyskie Mountains and its peripheries in relation to the remaining part of the voivodeship is also indicated by the snowing ratio. Calculated for the weather station Kielce (the relation of precipitation in the form of snow to total precipitation) is 18%, in relation to Sandomierz station 14% and Radom 14% (Biernat 1992).

The conditions for evaporation and shortages in precipitation in the area of Świętokrzyskie Mountains have been analyzed on the basis of the climatic water balance (the difference between total precipitation in a particular period and potential evaporation). Potential evaporation in vegetative season (IV-X) is from 630 mm in the north to 720 mm in the south-eastern part of the analyzed area (Fig. 4).

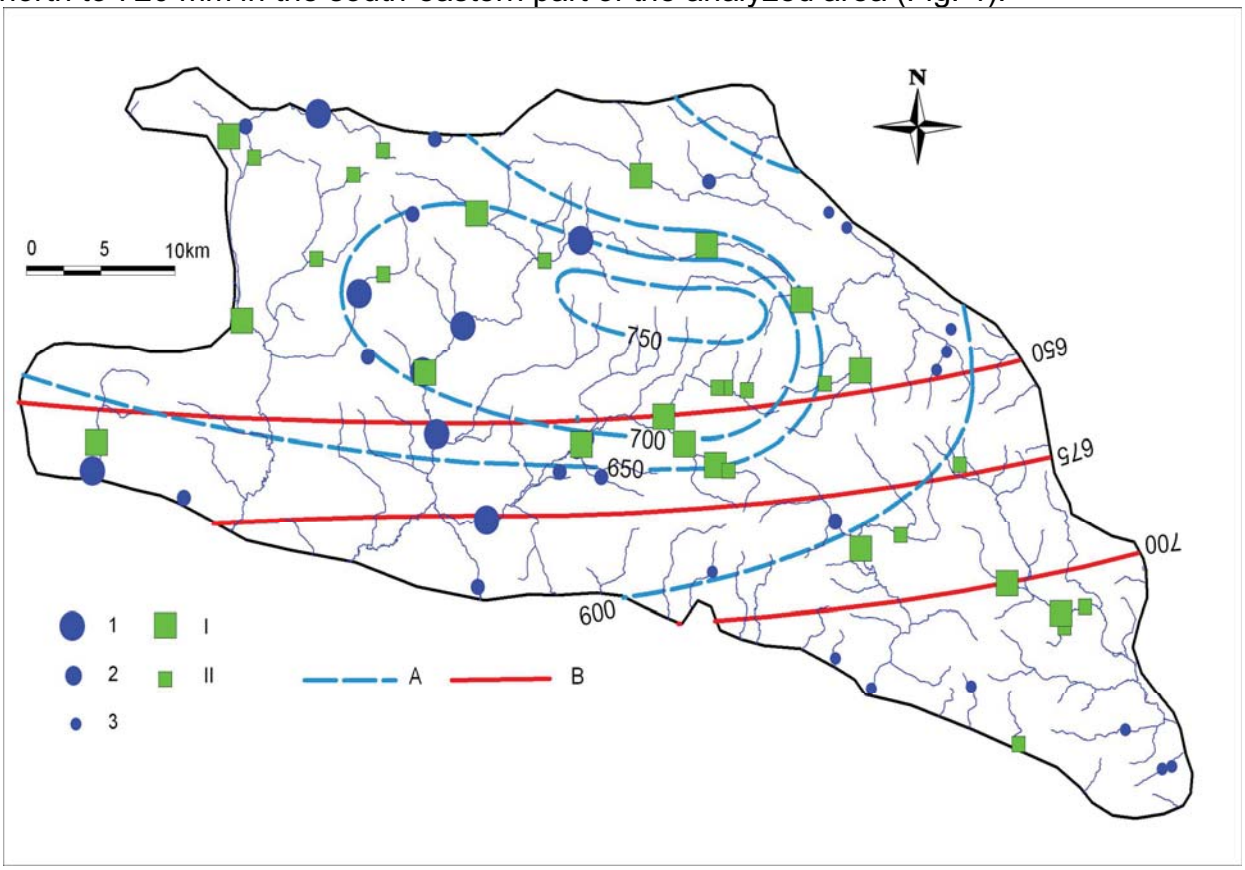

Fig. 4. **Existing water reservoirs (1 – above 10 ha, 2 – from 2 to 10 ha, 3 – below 2 ha) and planned (I – above 10 ha, II – below 10 ha) against of isohyets (year) and isotimes (summer period).**

The positive values of the balance occur only in the west and central parts of Świętokrzyskie Mountains, and negative in the remaining area. In the south-eastern part of the mountains the deficiency of precipitation in relation to evaporation possibilities exceeds 250 mm.

Designing a water reservoir charged by stream water demands the acquaintance of hydrologic characteristics. The water abundance of Świętokrzyskie Mountains catchment has been defined by the mean annual value of individual discharge. Within the catchment it shows large diversity. By the highest values in the period 1961-2000 are characterized the catchments, which drain Łysogóry (Belnianka to the range in Daleszyce – 7,7 $dm^3/s\ km^2$) and the western part of Świętokrzyskie Mountains (Lubrzanka – 6,4 $dm^3/s\ km^2$, Bobrza 6,1 $dm^3/s\ km^2$). Koprzywianka and Łagowica catchments are poor in water, where mean individual discharges do not exceed 4,5 $dm^3/s{\cdot}km^2$. In Koprzywnica catchment up to Klimontów mean annual individual discharge is only q = 3,7 $dm^3/s{\cdot}km^2$ and thus refers to mean values of the characteristics of the Polish low.

Essentials features of river discharge are represented well by characteristic individual discharges. In the period of the highest floods, individual discharges reached WWq = 442 $dm^3/s\ km^2$ in Belnianka catchment and over 300 $dm^3/s{\cdot}km^2$ in Koprzywianka (up to Klimontów), Lubrzanka and Bobrza catchments. They indicate the high dynamics of surface runoff, resulting from the location of the upper parts of the catchment in the area of the highest ranges in Świętokrzyskie Mountains, due to which their reaction for heavy precipitation is similar to the reaction of mountain catchments. An atipical example is Koprzywianka catchment discharge. Very high Wwq values are accompanied by the highest minimal discharges in the region NNq (0,14 $dm^3/s{\cdot}km^2$). Koprzywianka flows from the northern slopes of Jeleniowskie Range and initially flows through the area of diversified geomorphology. The particular character of the discharge of this river is influenced by the subsoil. Large part of the catchment consists of loess layers of high thickness. A dense network of seasonal and irregular steams was formed within the layers. Due to heavy precipitation, abrupt runoff along the slopes of large inclination takes place. In after-drought periods, due to the low location of groundwater surface, the underground charge of the river bed is small.

Within Świętokrzyskie Mountains there is a clear diversity of mean monthly values of individual discharge. The biggest values are in March (q_{max} = 14,7 $dm^3/s{\cdot}km^2$ – in Belnianka, in small catchments, e.g. Jaślana they exceed 16 $dm^3/s{\cdot}km^2$), and the smallest are in September (q_{min}= 1,7 $dm^3/s{\cdot}km^2$ – in Koprzywianka up to Klimontów). In the catchments of the discussed area the extremely high values of individual discharge exceed 200 $dm^3/s{\cdot}km^2$ in July.

In Świętokrzyskie Mountains, the areas embraced with various forms of nature preservation (i.a. 1 national park, 5 landscape parks, 4 areas of protected landscape, several nature and landscape complexes and a few dozens of ecological arable lands) occupy 90.5% of the area. Therefore, a significant number of existing and planned retention reservoirs is within their range. They need particularly rational rules of management and special treatment in plans for the changes made there.

In Świętokrzyskie National Park there are no water reservoirs of the area 1 ha, while in the buffer zone there are two retention reservoirs: Wilków on Święta Katarzyna effluent, and on Sieradowianka river (near Tarczek), and there are 8 in perspective of creation or modernization, in landscape parks and their buffer zones (partly corresponding to the areas of protected areas – 19, and in the unprotected areas – 5 objects (Fig. 5). It is worth noticing, that for the designed or modernized water reservoirs, there should be made detailed reports of their influence over the protected area. These assessments should indicate the legitimacy of building objects in this area, taking into account the restrictions established in the nature protection act for the mentioned forms of nature protection.

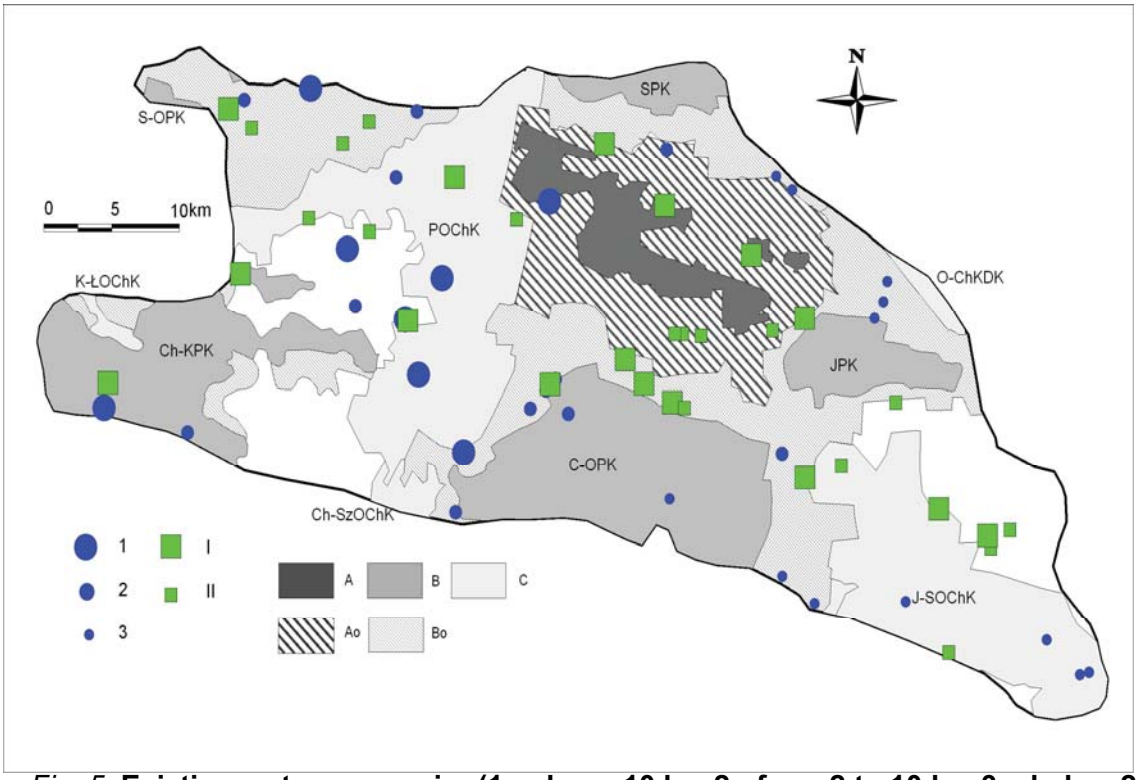

Fig. 5. **Existing water reservoirs (1 - above 10 ha, 2 - from 2 to 10 ha, 3 – below 2ha) and planned (I - above 10 ha, II - below 10 ha) against the geographical range of nature protection forms** (A – ŚNP; A_O – ŚNP buffer zone; B – landscape parks: Ch-KPK – Chęcińsko-Kielecki, S-OPK – Suchedniowsko-Oblegorski, SPK - Sieradowicki, JPK – Jeleniowski, C-OPK – Cisowsko-Orłowiński; B_O – landscape park buffer zone; C – areas of protected landscape: J-SOChK – Jeleniowsko-Staszowski, Ch-SzOChK – Chmielnicko-Szydłowski, K-ŁOChK – Konecko-Łopuszański, POChK – Podkielecki, OChKDK – Doliny Kamiennej).

One of the most important threats to the reservoirs results from their charge with relatively low quality waters. It is particularly noticeable in the agricultural catchment of Koprzywianka, where the erection of several water reservoirs is planned, and currently low quality of river waters (3rd class of purity) indicates the threats for their recreational function. The centrifugal layout of rivers discharging the forest areas of central part of Świętokrzyskie Mountains favoures the suggested location of the reservoirs (Fig. 6).

On Bobrza river, below the urbanized area of Kielce and its suburban zone, carrying the waters of low quality (sewage discharge from storm water drainage and treatment plants) no water reservoirs locations are planned.

Summary. The preferred trend as far as small retention in Świętokrzyskie Mountains is concerned, should be building and rebuilding of dams and weirs, especially in the locations where terrain conditions make it possible.

The structure of water balance in many areas of the discussed region is unfavourable. In the central part there is comparatively high precipitation (and accumulation of precipitation in the form of snow covering), diversified land forms with significant slope inclination covered with detritus, low permeability of the deeper soil layer. They affect the predominance of surface discharge over underground one, as well as significant contribution of melting discharge in annual discharge, which result in high flood waves. The situation indicates the necessity of the development all forms of water retention, restriction of direct discharge in favour of underground one. Furthermore, over long sections there are, narrow and deeply cut into the subsoil, river valleys favourable for interception with damming structures.

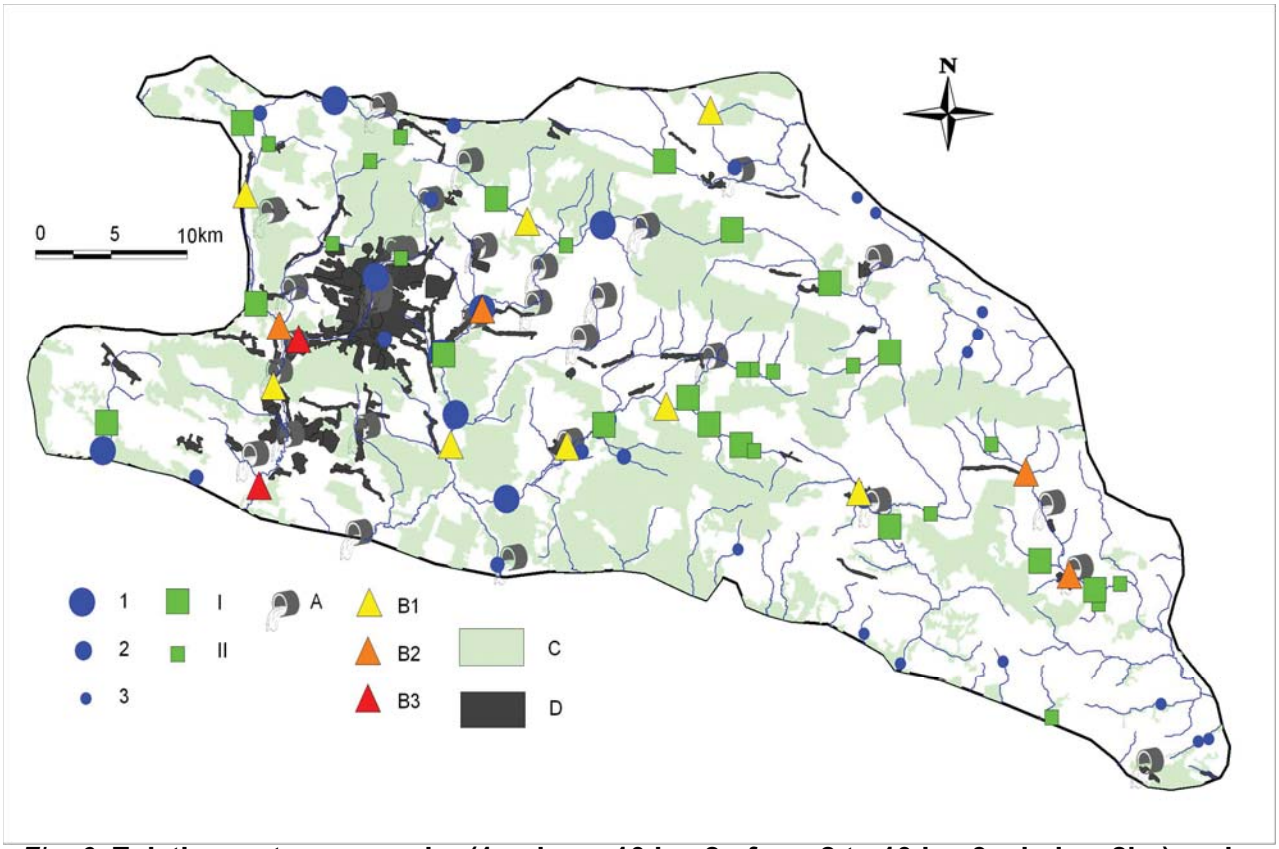

Fig. 6. **Existing water reservoirs (1 - above 10 ha, 2 - from 2 to 10 ha, 3 – below 2ha) and planned (I - above 10 ha, II - below 10 ha), sewage discharge locations (A) state of purity of river waters in WIOS cross section measurements (B) against forest complexes C) and urbanized areas (D).**

On the other hand, the location of small retention reservoirs is desirable in the areas of the poorest water resources due to climatic conditions (Koprzywianka and Czarna Staszowska catchments). The deficiency in precipitation in comparison to potential evaporation exceeds here over 200 mm a year. Periodic water shortages do not make it possible to fulfill economic needs or maintain good ecological condition of surface waters. What is more, the loess layer in the eastern part of Świętokrzyskie Mountains in the conditions of moderate atmospheric charge makes a layer favouring infiltration, but hardly drainable.

The factor in favour of the development of small retention forms is also economic activity connected with open pit exploitation of rock materials. The remains in the form of excavation often make good conditions for water retention. It is confirmed by the existence in the analyzed area of many small retention object located in quarries, sandpits or gravel pits). On the other hand, open pit mining (alongside the excessive exploitation of underground waters) contributed to the creation of drainages and depression cones.

The factor restricting the possibility of a free location of small retention water reservoirs in Świętokrzyskie Mountains is a large contribution of protected areas. There is a conflict between natural environment protection duties in these areas and the influence of potential water reservoirs on the environment and later water management. In such situations, it is necessary to define particularly rational rules of management.

Most of the existing and planned water reservoirs in the area of Świętokrzyskie Mountains play, apart from retention, a recreational role. Particularly important here is the quality of waters charging the reservoir, which is nevertheless, unsatisfactory in many watercourses, and hereby restricting the tourist allocation of the mentioned objects.

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The conditions for the location of small water retention reservoirs in Świętokrzyskie Mountains (Poland)

Tadeusz Ciupa, Roman Suligowski, Tadeusz Biernat

The aim of the elaboration is to show the selected natural and anthropogenic conditions, which determine the location of small water reservoirs in Świętokrzyskie Mountains. Świętokrzyskie Mountains are a physiographic mesoregion in the area of 1680 km^2 drained by Nida, Kamienna, Czarna and Koprzywianka. The analyzed area is entirely located in Świętokrzyskie Voivodeship.

In Świętokrzyskie Mountains there are 31 small water retention reservoirs (>1 ha). Most of them are located in Nida catchment (17). There are plans for creation (by 2020) of 32 water reservoirs of the area of at least 1 ha. Most of the discussed objects are designed for retention and recreation, part – for flood control, power engineering, angling.

There are two groups of factors, which determine the location of small retention objects: natural and anthropogenic ones. The former group includes the lithological features of soil and components of climate. In the latter group, determined by human activity, there are: utilization and land development factors, which influence the circulation dynamics and quality of waters.

Keywords: *water reservoir, small retention, Świętokrzyskie Mountains.*

Умови розташування малих водосховищ в Свєнтокшинських Горах (Польща)

Тадеуш Цюпа, Роман Суліґовскі, Тадеуш Бєрнат

Мета розробки – дослідити природні і антропогенні чинники, які визначають розташування малих водних резервуарів в Свєнтокшиських Горах - фізико-географічному мезорегіоні площею 1680 км^2, який дренується річковими системами Ніди, Камєнної, Чорної та Конжив'янки. Тут є 31 мале водосховище площею понад 1 га. До 2020 року планується побудувати ще 32 водосховища. Більшість з них є регуляторами стоку, мають гідроелектростанції. Серед природних чинників функціонування водосховищ є літологічний склад порід та клімат. Серед антропогенних виділяються характер забудови території та наявність промислових та побутових відходів. Обидва фактори визначають динаміку кругообігу та якість води.

Ключові слова: *водосховище, малі резервуари, Свєнтокшиські гори.*

Условия размещения малых водохранилищ в Свентокшинских Горах (Польша)

Тадеуш Цюпа, Роман Сулиговски, Тадеуш Бернат

Цель разработки - исследовать природные и антропогенные факторы, которые определяют расположение малых водных резервуаров в Свентокшиских торах - физико-географическом мезорегионе площадью 1680 км^2, который дренируется речными системами Ниды, Каменной, Черной и Конживьянки. Здесь есть 31 малое водохранилище площадью более 1 га. К 2020 году планируется построить еще 32 водохранилища. Большинство из них являются регуляторами стока, имеют гидроэлектростанции. Среди природных факторов функционирования водохранилищ литологический состав пород и климат. Среди антропогенных выделяются характер застройки территории и наличие промышленных и бытовых отходов. Оба фактора определяют динамику круговорота и качество воды.

Ключевые слова: *водохранилище, небольшие резервуары, Свентокшиские горы.*

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