Runoff formation in terms of changes in land use – Mściwojów water reservoir area

Artur RADECKI-PAWLIK[1] [ABDE], Andrzej WAŁĘGA[2] [ABCD], Jakub WOJKOWSKI[3] [ABDF], Jacek PIJANOWSKI[4] [ADEF]

[1] University of Agriculture in Kraków, Department of Water Engineering and Geotechnics, al. Mickiewicza 24-28,
   30-059 Kraków, Poland; e-mail: rmradeck@cyf-kr.edu.pl
[2] University of Agriculture in Kraków, Department of Sanitary Engineering and Water Management, Poland
[3] University of Agriculture in Kraków, Department of Ecology, Climatology and Air Protection, Poland
[4] University of Agriculture in Kraków, Department of Agricultural Land Surveying, Cadaster and Photogrammetry, Poland

Abstract

Along the paper the size of peak runoff was assessed affected by the influence of changes in water catchment area by land use due to future planned agricultural changes. The investigations were conducted in the Winna Góra catchment area located in Mściwojów, Lower Silesian voivodship at the Mściwojów water reservoir. At present, the catchment is used as arable land, forest and meadows. In the future the area of sealed surfaces such as: roofs, roads and car parks will increase. This can contribute in the change of water balance components. Analyses has shown, that changes in the use of a catchment area lead to reduction of surface flow time from the catchment (less resistance to motion) – in effect it causes increase of the runoff volume at about 28%. The increase of the water runoff volume may have significant influence on the Winna Góra development and functions as well as volume of water run into the Mściwojów water reservoir. To counteract the results of adverse changes caused by the catchment sealing – it is recommended for the investigated area to apply a balanced approach. This would consist of retaining precipitation water in its place of origin.

Key words: *balanced catchment development, concentration time, runoff, water reservoir*

INTRODUCTION

Floods are natural and seasonal phenomena, which play an important role in the environment. The problem occurs when flooding appears on man heavily invested areas, which results in the growing risk of substantial loss of life and property.

The growing degree of urbanisation leads to the increase of the number of impermeable surfaces in the catchment basin. Consequently often occurring tempestuous rain falls in spring are the main cause of rising violent surface water flows. This results in local flooding of the lowest located areas. It is estimated that in undisturbed grounds nonsealed and covered by natural plants surfaces the runoff amounts approximately to 10% of the rain fall. The rest is subject to evapotranspiration (40%) and infiltration (50%). In the catchment basin with a sealing degree from 75 to 100%, surface runoff of the rain fall is equal 55%, evapotranspiration (30%) and amount of infiltrating water is approximately 15% [WAŁĘGA, RADECKI-PAWLIK 2013; ZEVENBERGENET *et al.* 2011].

As a direct result of the process of urbanization, adverse effects in hydrological processes in the catchment take place. They manifest themselves in the increased incidence of extreme hydrological events (floods which affects not only the river channel morphology but also the ecological state of rivers

[WYŻGA *et. al* 2012a, b; 2013] and stream flow droughts which that is also due to situation when in the gravel of the river bed one can expect more water than in the river channel [CARLING *et al.* 2006]). For example, the research associated with the occurrence of a flood risk on the Kielce agglomeration area revealed, that in the highly urbanized Silnica catchment (as a result of flows which occur on average once every 100 years), the flood area will be nearly 150 hectares and will cover heavily invested areas [ŚLIZEWSKI *et al.* 2012]. The correct estimation of the parameters which characterizes the degree of risk of the occurrence of floods, as a result of catchment land use changes, is very important. Knowledge of the magnitude of the risk will allow actions to be taken, which will mitigate the adverse effects in the spatial management of the catchment. For example, in the aforementioned catchment area of the Silnica River, the reduction of the maximum flow on the outlets of the rainwater drainage due to water retention enlargement, will cause a decrease in the average depth of the flooding from a few to several cm and a reduction of the maximum depth of flooding from 30 cm to 70 cm. Smaller depths and the lessen extent of flooding will have the impact on reducing the negative consequences and reduction of overall losses caused by flooding [WOŹNIAK-VECCHIE *et al.* 2012].

The aim of the work is to determines the influence of changes in use of Winna Góra on the maximum amount of water runoff as a result of torrential rainfall. The paper presents the results of the work carried out under the project: "Valorisation and Sustainable Development of Cultural Landscapes using Innovative Participation and Visualisation Techniques", implemented within the Central Europe Program.

WINNA GÓRA RESEARCH AREA AND MSCIWOJÓW WATER RESERVOIR CATCHMENT

The research area Winna Gora at the Mściwojów water reservoir is placed in Sudeckie Foothills macroregion in Strzegomskie Hills mesoregion [KONDRACKI 1998]. It possesses features characteristic for a piedmont area. Mściwojów reservoir drainage basin is the hilly space and almost all area is occupied by farming grounds with dominance of arable land (Phot. 1, 2).

The Wierzbiak River is a right-bank tributary of the Kaczawa River in the Odra River basin. In the upper section of the Wierzbiak River, in the neighborhood of Mściwojów town, water reservoir (Phot. 2) was built and came into use in 2000 [PIJANOWSKI *et al.* 2013; SZAFRAŃSKI, STEFANEK 2008]. Its main purpose is agricultural usage of stored water and fire protection. Apart from the Wierzbiak River there is left-bank tributary named the Kałużnik which flows into the Mściwojów water reservoir.

Phot. 1. General view of the Mściwojów water reservoir (photo *J. Pijanowski*)

Phot. 2. The Mściwojów water reservoir dam (photo *J. Pijanowski*)

Total surface of the Mściwojów water reservoir drainage basin at the mouth of the river from the water basin is 49.12 km^2, from which 35.72 km^2 falls on the Wierzbiak River and 13.40 km^2 – on the Kałużnik River one (Fig. 1–5). The drop of drainage basin is 160.6 m and its mean fall is 11.5%. The area of Winna Góra is situated in the vicinity of Mściwojów village, Lower-Silesian Voivodship and neighbors directly with the Mściwojów reservoir. Its area of the Winna Góra is 11.87 hectares. In table 1 fundamental morph metric characteristics of investigated area are presented [RADECKI-PAWLIK *et al.* 2013].

Analysis of the present status of development of the Winna Góra area was performed based on information included in The Topographic Objects Base (TBD), in scale 1:10 000 and in topographic maps scale 1:10 000. In the investigated area at present, there are grasslands, arable land and forest (Phot. 3). Grassland from an economic point of view do not have a large value. The composition of the existing vegetation is: fescue, common quaking grass, herbs and weeds: wild thyme, spurges. Because of the very deep level of the ground waters table, vegetation of plants in this zone have adapted first of all by the amount of precipitation and the conditions of their infiltration to the subsoil.
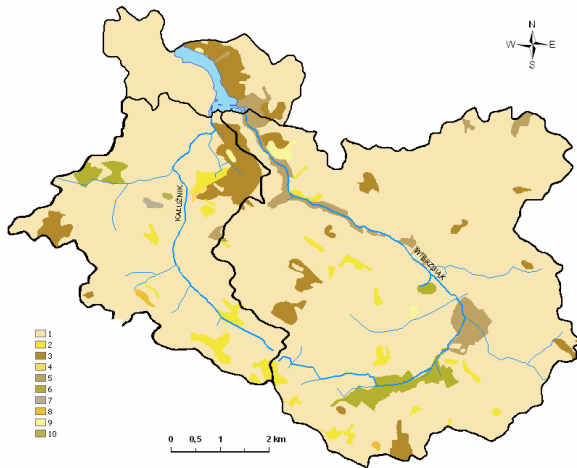
Fig. 1. The map of soil kinds in the Mściwojów water reservoir drainage basin: *1* – loess, *2* – silty clay loam, *3* – loam, *4* – loamy sand, *5* – sand, *6* – silty clay, *7* – silt loam, *8* – sandy loam, *9* – loamy very fine sand, *10* – sandy clay loam; source: own study
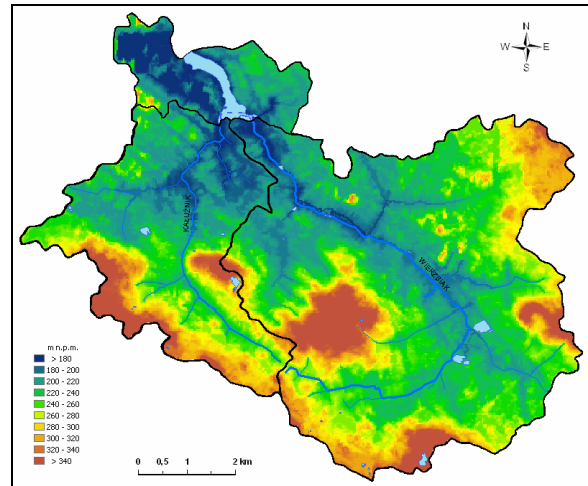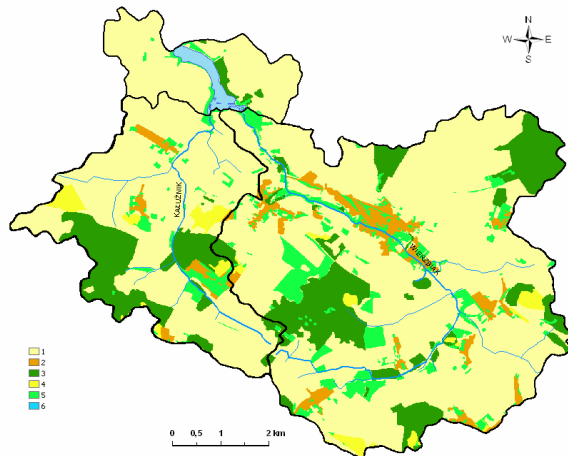

Fig. 2. The map of land cover of the Mściwojów water reservoir drainage basin: *1* – agricultural areas, *2* – urban areas, *3* – forests, *4* – artificial, non-agricultural vegetated areas, *5* – grassland, *6* – water bodies; source: own study

Fig. 3. The map water bodies in the catchment area; source: own study

Fig. 4. The map slopes of the Mściwojów water reservoir drainage basin; source: own study
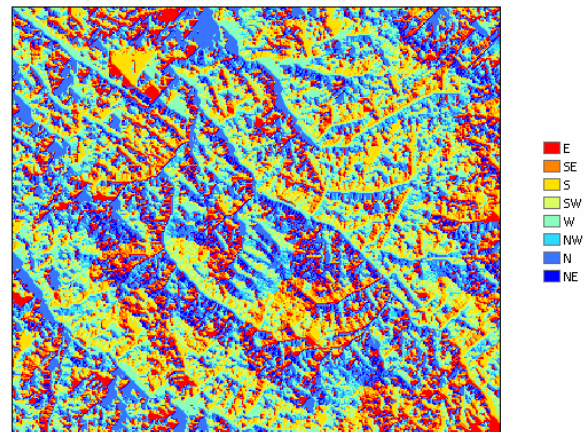

Fig. 5. The map of directions of runoff in the Mściwojów water reservoir drainage basin; source: own study

Table 1. Morphometric characteristics of Winna Góra area

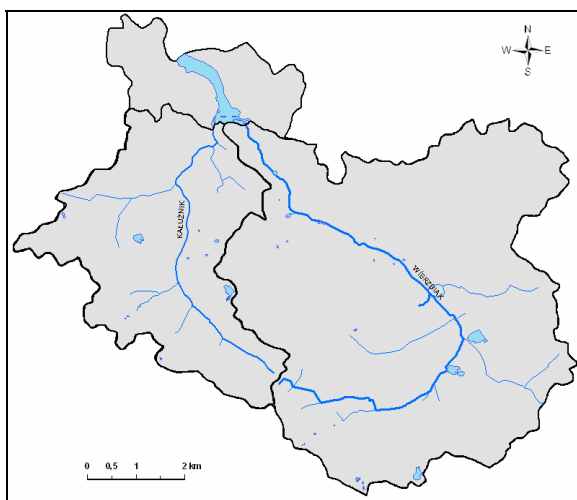| Parameter	Value
Area, m²	117 800
Maximum height H_{max}, m a.s.l.	209.20
Minimum height H_{min}, m a.s.l.	193.70
Length of the drop line from the top of the mountain to the reservoir L, m	165.0
Average slope $J_{śr}$, %	9.40

Source: own study.

Phot. 3. The view of the present state of the Winna Góra (photo *J. Pijanowski*)

Planned development of Winna Góra from the side of Mściwojów reservoir takes the following form:
– number of new designed buildings – 2,
– real area of roofs of designed buildings – 2 783 m^2,
– area of designed car park – 840 m^2,
– area of designed playground and tennis courts – 1 157 m^2,
– length of roadway (bitumen roads) – 941 m,
– area of roadway (bitumen roads) – 5 175 m^2,
– length of planned pathways – 1 230 m,
– area of planned pathways – 3 690 m^2,
– area of planned vineyard – 22 966 m^2.

The remaining area constitute grasslands. Below Figure 6 presents the visualisation of the planned development of Winna Góra.

Fig. 6. Visualisation of concept of Winna Góra in Mściwojów development; source: own study

METHODS

In view of the planned investments in the changing of Winna Góra land use, the question arises – how will the planned revision of the housing stock, particularly an increase sealing of the part of the catchment, will influence the formation of the runoff. To answer this question, it is necessary to assess the size of the runoff, in terms of current and planned future land use. Due to the complex circulation of water in the catchment, with a high degree of sealing, the answer is burdened with the high degree of difficulty and the results can be regarded as estimates. In order to determine the influence of buildings on the size of the runoff from Winna Góra, two-step hydrological calculations were conducted. In the first stage the size of the runoff in terms of current land use was estimated, in the second stage – in terms of the planned land use. In both stages, the same input data concerning rainfalls were adopted. Due to the small size of the catchment (equal 117 800 m^2), the size of the runoff was calculated using the method of flow time, also known in the literature as the rational method. The size of the runoff according to the rational method in m$^3 \cdot$s^{-1}, is calculated from the formula listed [MAIDMENT 1993]:

$$Q = 0.278 q_m\, C\, A \qquad (1)$$

where:
q_m – meaningful rainfall intensity, mm·h^{-1};
C – dimensionless runoff coefficient;
A – catchment area, km^2.

It is a formula based on the so called block precipitation of rain, with a constant intensity for a given duration of time and frequency of appearance. In view of the considerable simplification used in this method, it is assumed that the rational formula may be used to calculate the flow of the peak flow in small urbanized and rural catchments, representing an area of 2.5 km^2. In practice, for the calculation of runoff from the catchment, the rainfall of a certain probability of occurrence is taken. In the formula, flow coefficient C is allowed to include in the calculation: precipitation loss on interception, infiltration, surface retention, evapotranspiration and terrain evaporation and rising wave flattening. Its values are dependent of the catchment management, its slope and rainfall intensity. In practice, the runoff coefficient values are determined according to the land use [PONCE 1989].

Due to the different land cover for a proposed building the weighted average runoff coefficient formula was determined:

$$C_z = \frac{C_1 A_1 + C_2 A_2 + ... + C_i A_i}{A_1 + A_2 + ... + A_i} \qquad (2)$$

where:
C_i – weighted average runoff coefficient for the i-th partial surface (–);
A_i – the value of the i-th partial catchment area, km^2.

The intensity of meaningful rain is the second parameter next to runoff coefficient, which significantly affects the size of the runoff. Precipitation characteristics, which have to be established before carrying out actual calculations is the duration time t and the probability of the occurrence p. In the case of small catchments, it can be assumed that the precipitation is evenly distributed and that it has a constant intensity over the whole catchment area. Thus maximum runoff in the tested cross-section will occur in the situation, when the whole catchment will take part in the formation of runoff [SHAW et al. 2011]. Critical duration of rain, where there occurs the maximum runoff is named the time of concentration. In the absence of a clear draining stream in the analyzed area, there is only the surface runoff to estimate the characteristics, so the method based on solving the kinematic wave equation was used in the following form [WAŁĘGA et al. 2013]:

$$t_{c1} = \frac{6.92}{i^{0.4}} \left(\frac{nL}{\sqrt{s}} \right)^{0.6} \qquad (3)$$

where:
n – Manning roughness coefficient depending on the kind of the surface (–) – Table 2;
L – the flow path length, m;

I –   intensity of rain, mm·h^{-1};
S –   slope of the flow path, m·m^{-1}.

Table 2. Values of land roughness factor n

Description of surface	n
Concrete, asphalt, flat land with no vegetation	0.011
Gravel, terrain with varying topography	0.02
Cultivated land	
vegetation ground cover <20%	0.06
vegetation ground cover >20%	0.17
crops (mature crops)	0.3
fallow	0.5
Grass	
short and sparse vegetation	0.15
dense turf	0.24
very dense grass, tall, flat surface	0.41
pastures	0.20
Forests	
poor brushwood	0.40
dense brushwood	0.80

Source: USDA [1986].

In view of the fact, that occurring in the formula above rainfall intensity I depends on its duration, time of the surface flow must be calculated using iterative methods. In the first stage of the calculation, the concentration time is assumed and then the intensity of rains calculated for the taken time period and probability of occurrence. Knowing I we calculate t_{c1}. Calculations are run until the moment when assumed time of concentration is similar to that obtained from the formula above. The calculation of the intensity of the rain were performed for the duration t equal to concentration time (for current and prospective development) and for probabilities of precipitation equal p = 1, 5, 10, 20 and 50%. The amount of precipitation for a specified time period and probability and next its intensity I (in mm·h^{-1}), were calculated from the formula of Bogdanowicz–Stachý [BOGDANOWICZ, STACHÝ 1998]:

$$P_{max(t,p)} = 1{,}42t^{0.33} + \alpha(-\ln p)^{0.548} \qquad (4)$$

where:
t –   the duration of the rain, min;
p –   probability;
α –   the location and scale parameter, mm.

Parameter α is determined on the basis of the location of the object in question and the precipitation duration time t. Taking into account location of the analyzed catchment, parameter α has been set for the South region.

RESULTS AND DISCUSSION

The basic parameter occurring in the rational formula is the intensity of rain. It's calculated values are summarized in Table 2. It depends on the probability and duration of rain. Value of C – responsible for the duration of the rain, has been established based on the time of concentration. This characterizes the

duration of water runoff from the farthest point of the catchment to the runoff cross-section. One of the reasons for the decision on the kinematic wave method adoption, is to determine the time of concentration and a willingness to take into account the type of flow surface and precipitation kind. Calculations of the time of concentration made for the runoff surface slope S = 0.094 m·m^{-1}, length of runoff path L = 165 m, roughness coefficient of the runoff surface equal n = 0.24 (the current land management – wasteland, grasslands) and n = 0.18 (for the prospective development – roof surfaces, roads, car parks, vineyards). The increase in the degree of the catchment sealing will result in a faster runoff (shorter times of concentration) which will lead to an increase in the intensity of rain for the same probabilities – Table 3 and Figure 7. As a result, runoff larger values will be observed.

Table 3. Rainfall intensity of duration t equal to concentration time for different probabilities.

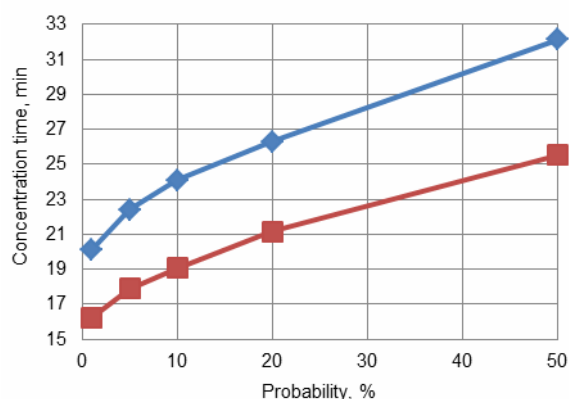| Probability	Rainfall intensity, mm·h^{-1}	
	current building	prospective building
1	101,80	113,14
5	77,70	88,70
10	64,85	75,74
20	52,20	58,41
50	31,61	36,44

Source: own study.

Fig. 7. Influence of catchment area development on the amount of concentration time for rains of with different probabilities: in blue the present state of the area is presented in terms of the number of buildings in red – that what is planned; source: own study

As a result of increased catchment sealing times of concentration became shorten from 4 minutes for the rain with p = 1% to 7 minutes for the rain with p = 50%. In case of rains with a very heavy intensity,(in case of low probabilities)within a short period of time falls on a catchment, a large amount of water leads to the situation in which the catchment's ability of retention is rapidly lost, regardless of its use. This explains the situation, that by the precipitation of a higher intensity, the change of the time of concentration as a result of differences in the use of catchment is smaller, than by less intense rainfall. Time of concen-

tration increases with increasing probability of rain. This is because with a higher probability, rainfall intensity is lower and therefore less water reaches the given surface, hence the rate of runoff will be smaller. Thus, precipitation characteristics play an important role in calculating the time of concentration. The conclusion is that hydraulic methods for calculating the time of concentration produce more accurate results than the empirical methods (for example, methods of Kirpich or Kerba [WEINEROWSKA-BORYS 2010]), as they take into account the whole complexity of the runoff process.

Below presented table 4 summarizes the results of calculations of the size of surface runoff from the Winna Góra area for current building and prospective building and different probabilities of rain.

Table 4. The values of the maximum probable flow in Winna Góra catchment for various developments

Probability	Maximum flow, $m^3 \cdot s^{-1}$	
	current building; $C = 0.36$	prospective building $C = 0.44$
1	1.200	1.630
5	0.916	1.278
10	0.764	1.091
20	0,615	0,842
50	0,373	0,524

Source: own study.

Assuming, that the volume of runoff coefficient for the current building will be $C = 0.36$ (as for uncultivated and arable land), size Q_{max} will vary from 1.20 $m^3 \cdot s^{-1}$ for $p = 1\%$ to 0.373 $m^3 \cdot s^{-1}$ for $p = 50\%$. With an increase of the degree of catchment sealing (weighted average runoff coefficient $C = 0.44$), the volume of maximum flow will increase on average about 28% in relation to the current building. As a result of the catchment area development with parking lots and roads, this diminishes the amount of rain water which may infiltrate into the ground which leads to an increase in the volume of runoff. This increase could have a significant impact on the development of the Winna Góra (for example, the potential intensification of the erosion processes) but little effect on the Mściwojów water reservoir. In order to reduce the impact of catchment sealing on the volume of runoff, solutions on the rapid draining of excess water are applied (traditional rain water drainage channels in the open and closed form) or a balanced approach. Using the first approach, it is possible to get rid of the problem in a place. That is the risk, as a result of changes in the water circulation, the problem moves to the lower parts of the catchment, often causing a much more serious threat, than before the drainage was made [TUCCI 2007]. A balanced approach would consist in the application of the planning and technical methods in the whole catchment. This consists in delaying the runoff and increasing the catch-

ment water storage capacity. Delaying the runoff by increasing the time of concentration will reduce water runoff and relieve water reservoirs from excessive runoffs caused by tempestuous rainfalls, and may reduce the effects of water erosion [MIGUEZ, DE MAGALHAES 2010]. In this approach rain will be restrained at the place of its occurrence in such solutions retention basins, permeable pavements, retention and infiltration reservoirs, etc. Taking into account the characteristics of the investigated area, to stop the precipitation in the space of origin it is possible to use the complete solution to the management of precipitation like from a car park, in which there are several different systems (bio-retention, underground systems of drainage boxes, permeable pavement [EPA 2007; WAŁĘGA 2010; WAŁĘGA et al. 2013]. In the case of roofs areas, especially in newly designed buildings, green roofs can be used or rain waters can be used for the needs of the household. This contributes to a significant reduction in the consumption of tap water. In addition these solutions to the retention function for rainwater runoff also affect the retention of significant amounts of impurities contained in the run-off from the polluted surfaces like roads or car parks.

RECAPITULATION

This paper assesses the impact of catchment area use and changes on the size of the maximum runoff. The study was carried out within the project "Valorization and Sustainable Development of Cultural Landscapes use Innovative Participation and Visualization Techniques", implemented within the framework of the Central Europe program. Analyses were carried out in the area of Winna Góra, located in the village of Mściwojów in the vicinity of the Mściwojów reservoir. Currently, the area is mainly used for agriculture. In the future, it is planned to increase the area sealing through the construction of roads, car parks and buildings. The influence of the catchment sealing on the runoff volume was determined using the indirect method of calculation in two versions, current and prospective development. Analyses showed that increasing catchment sealing leads to a reduction of surface runoff time from the catchment (less resistance to motion) which will lead to an average of 28% increase in volume of the runoff. This increase of the water volume of the runoff can have a significant impact on the development of Winna Góra (for example, the potential intensification of the erosion processes). In order to counteract the effects of these adverse changes, as a result of the catchment sealing, it is recommended that the balanced approach involving the retention of the precipitation in the place of origin for the investigated area be used. For this purpose it is also recommended that, the devices for retention and infiltration of precipitation from the different kinds of building should be used.

REFERENCES

BOGDANOWICZ E., STACHÝ J. 1998. Maksymalne opady deszczu w Polsce – charakterystyki projektowe [Maximum precipitation in Poland – design characteristics]. Materiały Badawcze IMGW. Nr 23. Ser. Hydrologia i Oceanologia. Nr 85. ISSN 0239-6297 pp. 85.

CARLING P., WHITCOMBE L., BENSON I., HANKIN B., RADECKI-PAWLIK A. 2006. A new method to determine interstitial flow patterns in flume studies of sub-aqueous gravel bedforms such as fish nests. River Research and Applications. Vol. 22. Iss. 6 p. 691–701.

EPA 2007. Urban stormwater retrofit practices. Urban Subwatershed Restoration Manual Series, Manual 3. Washington.

KONDRACKI J. 1998. Geografia regionalna Polski [Regional geography of Poland]. Warszawa. Wydaw. Nauk. PWN. ISBN 8301124792 pp. 440.

MAIDMENT D.R. 1993. Handbook of hydrology. New York. McGraw-Hill Inc. ISBN 0070397325 pp. 1424.

MIGUEZ M.G, DE MAGALHAES L.P.C. 2010. Urban flood control, simulation and management – an integrated approach. In: Methods and techniques in urban engineering. Eds. A.C. de Pina Filho, A.C. de Pina. Rijeka. InTech. p. 131–160.

PIJANOWSKI J., RADECKI-PAWLIK A., WAŁĘGA A., WOJKOWSKI A. 2013. Evaluation of soil water erosion risk in the Mściwojów water reservoir drainage basin on the basis of numeric modeling. Geomatics, Landmanagement and Landscape. No. 1 p. 83–97.

PONCE V.M. 1989. Engineering hydrology: Principles and practices. Upper Saddle River, New Jersey. Prentice Hall. ISBN 0132778319 pp. 531.

RADECKI-PAWLIK A., WAŁĘGA A., WOJKOWSKI J. 2013. Influence of changes in land use on the values of maximal peak flows on example of Winna Góra in the neighbourhood of Mściwojów reservoir. Geomatics, Landmanagement and Landscape. No. 2 p. 101–112.

SHAW E.M., BEVEN K.J., CHAPPEL N.A., LAMB R. 2010. Hydrology in practice. 4th ed. London, New York. Spon Press. ISBN 0415370426 pp. 560.

ŚLIZEWSKI B., WOŹNIAK-VECCHIE R., ZIÓŁKOWSKI L., SZCZĘŚNIAK M., WAŁĘGA A., ZIÓŁKOWSKA E. 2012. Oddziaływanie zrzutów z kanalizacji deszczowej na zagrożenie powodziowe na przykładzie miasta Kielce. W: Hydrotechnika XIV 2012 [The influence of rain waters on the flood protection system of Kielce. In: Hydrotechnique XIV 2012]. Materiały Sympozjum. Ustroń.

SZAFRAŃSKI Cz., STEFANEK P. 2008. Wstępna ocena wpływu zbiornika Mściwojów na przepływy w rzece Wierzbiak i głębokości zwierciadła wody gruntowej w terenach przyległych [Base assessment of the Msciwojow water reservoir influence on the Wierzbiak River on adjacent area]. Rocznik Ochrony Środowiska. T. 10 p. 491–502.

TUCCI C.E.M. 2007. Urban flood management. WMO/TD. No. 1372. pp. 303.

USDA 1986. Urban hydrology for small watershed. TR-55 pp. 164.

WAŁĘGA A. 2010. Watershed urbanization: influence on the environment and possibility of counteraction. In: Cultural landscapes of river valleys. Eds. A. Radecki-Pawlik, J. Hernik. Kraków. Wydaw. UR. ISBN 978-83-60633-42-7 pp. 260.

WAŁĘGA A., RADECKI-PAWLIK A., KACZOR G. 2013. Naturalne sposoby zagospodarowania wód opadowych [Natural ways of managing rainfall waters]. Kraków. Wydaw. UR. ISBN 8360633649 pp. 235.

WEINEROWSKA-BORYS K. 2010. Czas koncentracji w uproszczonych obliczeniach odpływu ze zlewni zurbanizowanych. W: Hydrologia w inżynierii i gospodarce wodnej [Time concentration calculations for outflows from urbanised areas. In: Hydrology in engineering and water management]. T. 1. Ed. B. Więzik. Monografie Komitetu Inżynierii Środowiska PAN. Vol. 68 Warszawa p. 367–377.

WOŹNIAK-VECCHIE R., WAŁĘGA A., ŚLIZEWSKI B., ZIÓŁKOWSKI L., SZCZĘŚNIAK M., ZIÓŁKOWSKA E. 2012. Modelowanie oddziaływania odpływu z kanalizacji deszczowej na odbiorniki w zlewniach zurbanizowanych. W: Infrastruktura komunalna i gospodarka wodna [Modeling of outflow from urbanised canalisation systems and their influence on water reservoirs. In: Municipal infrastructure and water management]. Materiały III Międzynarodowej konferencji naukowo-technicznej pod patronatem Komitetu Inżynierii Środowiska PAN. Rzeszów. INFRAEKO.

WYŻGA B., OGLĘCKI P., RADECKI-PAWLIK A., SKALSKI T., ZAWIEJSKA J. 2012a. Hydromorphological complexity as a driver of the diversity of benthic invertebrate communities in the Czarny Dunajec River, Polish Carpathians. Hydrobiologia. Vol. 696. Iss. 1 p. 29–46.

WYŻGA B., ZAWIEJSKA J., RADECKI-PAWLIK A., HAJDUKIEWICZ H. 2012b. Environmental change, hydromorphological reference conditions and the restoration of Polish Carpathian rivers. Earth Surface Processes and Landforms. Vol. 37. Iss. 11 p. 1213–1226.

WYŻGA B., OGLĘCKI P., HAJDUKIEWICZ H., ZAWIEJSKA J., RADECKI-PAWLIK A., SKALSKI T., MIKUŚ P. 2013. Interpretation of the invertebrate-based BMWP-PL index in a gravel-bed river: insight from the Polish Carpathians. Hydrobiologia. Vol. 712. Iss. 1 p. 71–88.

ZEVENBERGEN C., CASHMAN A., EVELPIDOU N., PASCHE E., GARVIN S., ASHLEY R. 2011. Urban flood management. Boca Raton. CRC Press. ISBN 0415559448340 pp. 370.

Artur RADECKI-PAWLIK, Andrzej WAŁĘGA, Jakub WOJKOWSKI, Jacek PIJANOWSKI

Odpływ powierzchniowy w rejonie zbiornika wodnego Mściwojów w świetle planowanych zmian urbanistycznych

STRESZCZENIE

Słowa kluczowe: *czas koncentracji, odpływ, zbiornik wodny, zrównoważony rozwój zlewni*

W artykule przedstawiono wielkość zmian odpływu powierzchniowego w wyniku przyszłych planowanych zmian użytkowania rolniczego zlewni. Badania prowadzono w obszarze Winnej Góry znajdującej się w miejscowości Mściwojów (województwo dolnośląskie) w zlewni zbiornika wodnego Mściwojów.

Obecnie zlewnia to głównie przestrzeń rolnicza i lasy. W przyszłości obszar powierzchni zlewni dopełnią powierzchnie takie, jak: budynki, drogi i parkingi. Może to przyczynić się do zmiany elementów bilansu wodnego zlewni. Analizy wykazały, że zmiany w użytkowaniu zlewni prowadzą do skrócenia czasu spływów powierzchniowych ze zlewni (mniejsze opory ruchu), co powoduje zwiększenie objętości odpływu o około 28%. Zwiększenie ilości odpływającej wody może mieć znaczący wpływ na rozwój i funkcje Winnej Góry, a także dopływ wody i pojemność zbiornika wodnego Mściwojów.