http://dx.doi.org/10.15576/GLL/2019.4.231

GLL

Geomatics, Landmanagement and Landscape No. 4 • 2019, 231–241

PRELIMINARY ASSESSMENT OF THE IMPACT OF WROCŁAWSKI BRIDGE IN GLIWICE ON FLOOD FLOW IN KŁODNICA RIVER

Bartłomiej Mikołajczyk, Bogusław Michalec, Mateusz Strutyński

Summary

In this work, a preliminary assessment has been made of the impact that the bridge along Wrocławska and Częstochowska streets has on the conditions of flood flow. Calculations were made for a flow with a probability of exceedance p = 1% amounting to 100 $m^3 \cdot s^{-1}$. Based on the field tests performed in the designated section of the Kłodnica river from km 49 + 799 to km 49 + 739, i.e. geodetic measurements of the Kłodnica riverbed and technical inventory of the analysed bridge object, a digital terrain model (NMT) was developed, followed by hydraulic calculations of the water flow $Q_{1\%}$ and the flow accumulation (damming) in the clear span of the Wrocławski bridge. The accumulation height was calculated using the formula given in the study by Bajkowski et al. [2000]. Calculations of the accumulation height of designed flow in the clear span of the bridge were also made using the HEC-RAS program. The calculations were made in two variants – in the first variant, calculations were performed for the selected section of Kłodnica without a bridge, and in the second variant, with the bridge. The so-called clear span reserve (bridge clearance) was also calculated, computed as the difference in ordinates of the keystone arch of the bridge span and the stacked water table of the design flow in the bridge clear span. The obtained calculation results indicate no risk of $Q_{1\%}$ flow accumulation in the cross-section of the Wrocławski bridge. The calculated accumulation of the design flow will not cause flooding from the Kłodnica riverbed. Preliminary conclusions indicate a possible necessity to verify flood hazard zones for the flow with a probability of exceedance p = 1%, developed for the Kłodnica river in the centre of Gliwice town, developed as part of the ISOK project.

Keywords

flood hazard • bridge • accumulation (damming) height • HEC-RAS

1. Introduction

The centre of Gliwice town is exposed to flooding caused by the Kłodnica river. In the last decade, such floods occurred in May 2010 and in July 2016. There are very frequent exceedances of alert thresholds of water level, for example, in 2014 Gliwice Rescue Centre [Centrum Ratownictwa Gliwice 2015] issued warnings about high water levels in the months of May, July, August and September, and in 2015 – in January, February, March, April, May and July. Due to the high water level and flood threat, it is necessary to protect the centre of Gliwice against flood and its effects. Flood protection is implemented while taking into account flood hazard maps, flood risk maps and flood risk management plans. Figure 1 presents the flood hazard map of the centre of Gliwice for the probability of flooding p = 1%. This area, according to information presented on the website of Gliwice Rescue Centre [Centrum Ratownictwa Gliwice 2015], is threatened with flooding as a result of rivers and streams overflowing, and the accumulation of rainwater or backwater in the rainwater drainage system. According to the Gliwice Rescue Centre, the main reason for the deterioration of the flood protection of the city of Gliwice after 1997 is the backfilling of the WN 35 reservoir located on the border of Zabrze and Gierałtowice, which had previously provided relief for part of the flood waters from the Kłodnica river.

Source: ISOK

Fig. 1. The map of threat and flood risk of the center of Gliwice, featuring the water depth *h* = 0.5–2.0 m, for the probability of flooding p = 1%

In the "Study of conditions and directions of spatial development for the city of Gliwice" [2009] nine basic actions necessary to reduce and eliminate flood risk are listed. Among these activities, the need to include structures in the development projects was listed, such as: culverts, bridges and embankments separating the valleys of rivers and streams, ensuring free flow of water, as well as the need to widen the clear span of the bridge along Wrocławska and Częstochowska streets, which causes the accumulation of Kłodnica river flood waters. In this work, an attempt was made to demonstrate the impact of the bridge in question on the flood flow conditions of the Kłodnica river with a probability of exceeding p = 1% of 100 $m^3 \cdot s^{-1}$. As a result of the tests it will be possible to make an initial assessment of the impact of the bridge along Wrocławska street on raising the water level above the bridge cross-section, and it will be possible to determine the impact of this bridge on flooding the centre of Gliwice town by flood flow with exceedance probability p = 1%. Determining the height of the accumulation of flood flows in the clear span of the bridge is important because the water accumulation below the bridge in consequence may lead to water overflow into the embankment, causing a threat of flooding to adjacent areas [Osman 2006].

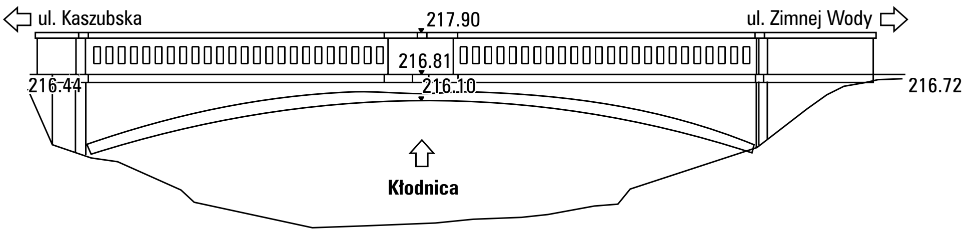
2. The studied object

The area of the city of Gliwice is located within two sub-provinces: the Central Poland Lowland (Nizina Środkowopolska) and the Silesia-Cracow Upland (Wyżyna Śląsko-Krakowska), as well as two macro-regions: the Silesian Upland (Wyżyna Śląska) and the Silesian Lowland (Nizina Śląska). The city is located in the area of the accumulation plain, crossed by the valley of the Kłodnica river [Kondracki 2002]. A characteristic element of the Gliwice landform consists in the lowering of the terrain, which runs from the south-east towards the north-west, and is connected with the Kłodnica riverbed. River valleys occurring in the city are primarily of longitudinal course. The exceptions are the valley of the Ostropka river and the valley of the Wójtowianka river, both of which have a latitudinal course. Such morphology of the terrain creates conditions that are conducive to flooding. In addition, as a result of intensive exploitation of mineral resources, mainly hard coal, there was a significant transformation of the area. At present, forms prevail here that are related to subsidence and collapse: sinkholes, settlement troughs, as well as dumps resulting from the storage of post-mining waste [Osowska and Kalisz 2016].

The catchment area of the Kłodnica river, which is a right-bank tributary of the Odra river, covers an area of 1,129.72 km^2, which is about 29% of the area of the Upper Oder Water Region. The Kłodnica catchment has a developed hydrographic network. Kłodnica is a river of submontane (piedmont) character. It is characterized by large differences in the slope of the riverbed, as well as variability of flows. Within the Katowice conurbation, in order to prevent water from entering the mining excavations, the Kłodnica riverbed was channelled, covered with concrete and/or paved practically along the entire length of its course [Nocoń et al. 2006]. Along the Kłodnica river, the Gliwice Channel (kanał Gliwicki) has been operating since 1939 [Wagner et al. 2012].

3. Research methodology

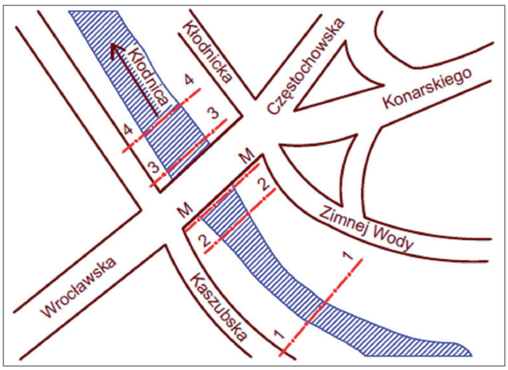
In order to determine the impact of the bridge along Wrocławska street (Fig. 2) at 49 km + 780 of the Kłodnica river on the conditions of flood flow, an analysis of the hydraulic conditions of the flood flow on this section of the river from km 49 + 799 to km 49 + 739 was conducted. The bridge, located at km 47 + 780 of the course of the Kłodnica river, it is an object constituting an element of the municipal transport infrastructure, between Wrocławska and Częstochowska streets. Regional road No. 901 crosses the studied bridge. It is a reinforced concrete structure with an arched, three-articulated vault.



Source: Authors' own study

Fig. 2. The Wrocławski bridge – bridge diagram developed on the basis of geodetic inventory measurements

The studied section of the Kłodnica river is located in the very centre of the city of Gliwice, in the area of streets: Wrocławska, Kłodnicka, Zimnej Wody, and Kaszubska. In order to perform hydraulic calculations of water accumulation (damming) in the cross-section of the bridge, cross-sections were determined in which geodetic measurements were made. Location of cross-sections 1–1 (km 49 + 799), 2–2 (km 49 + 791), 3–3 (km 49 + 769), and 4–4 (km 49 + 739) as well as MM bridge section (km 49 + 786) are shown in Figure 3. Geodetic measurements of the riverbed in the determined cross-sections were made using the Leica Sprinter 250M level. Additionally, ComNav GPS T300 receiver was used to determine the ordinates of the determined points in cross-sections. Based on the results of geodetic measurements, local river bottom gradients were determined. The analysis was prepared for the existing condition of the riverbed, including the natural biological development of the section of the riverbed of the Kłodnica river before the bridge, and past the bridge. For this purpose, during geodetic measurements, an inventory of the covering of the riverbed with vegetation cover was conducted, in order to adopt appropriate roughness coefficients from the table of Ven Te Chow.



Source: Authors' own study

Fig. 3. Location of cross-sections in Kłodnica river bed: 1–1 (km 49 + 799), 2–2 (km 49 + 791), M–M (km 49 + 786), 3–3 (km 49 + 769), and 4–4 (km 49 + 739)

Calculations of the height of flow accumulation (damming) in the clear span of Wrocławski bridge were made for the flow with a 1% probability of exceedance. This flow, adopted as the design flow, was determined for the Gliwice water gauge on the basis of hydrological data series from 1956–2010, is 100 $m^3 \cdot s^{-1}$ [Ekspertyza... 2012]. The accumulation (damming) height (Δz) of the design flow in the clear span of the bridge was determined using the empirical formula given in the study by Bajkowski et al. [2000]. This formula, applicable in the event of no blurring of the river bottom under the bridge, is the following:

$$\Delta z = K \cdot \frac{\alpha_m \cdot V_m^2}{2g} + \frac{\alpha_1 \cdot \left(V_2^2 - V_1^2\right)}{2g} \tag{1}$$

where:

- K – energy loss factor,
- α_m – St. Venant factor in the bridge cross section,
- α_1 – St. Venant factor in the section of the riverbed before the bridge,
- V_m – average flow velocity in the bridge cross section,
- V_1 – average flow velocity in cross section past the bridge, after the accumulation (damming),
- V_2 – average flow velocity in cross section below the bridge,
- g – gravitational acceleration.

Having determined the coefficients of the roughness of the bottom and slopes of the Kłodnica riverbed, as well as the determined decrease in the water level, which was assumed equal to the gradient of the river bottom over the tested section of 60 meters in length, the filling (wetted perimeter) in the developed cross-sections of the riverbed was calculated. These figures were determined as a result of developing the flow rate curve for each cross-section. In contrast, the flow rate curves were developed based on the calculated flow velocities for a given filling (wetted perimeter), using the Chezy formula, in which the Maninng coefficient of roughness was calculated using the Cowan method. Calculations of the flow rate curve were conducted according to the methodology used, among others, in works by Tarnawski and Michalec [2006] and Michalec and Tarnawski [2007]. Calculations of the accumulation (damming) of design flow were made in accordance with the methodology given in the study by Bajkowski et al. [2000].

The impact of the Wrocławski bridge on the conditions of flood water flow was also determined on the basis of the results of mapping the assumed design flow ($Q1\% = 100$ $m^3 \cdot s^{-1}$) in the HEC-RAS software application. It is a program commonly used to designate flood risk zones [Książek et al. 2010], or the catastrophic flow [Klaja et al. 2007]. As demonstrated by Michalik and Książek [2009], Plesiński et al. [2017], this model can be a helpful tool in calculating bed load transport. Calculations in the HEC-RAS software application version 5.0.3, which is a mapping of the water flow in the riverbed of the Kłodnica river, were made for two hydraulic models (in two variants) of the analysed section of the river including the Wrocławski bridge. In the first variant, calculations were made using a hydraulic model with the help of which the height of the water table was determined on the analysed section of the riverbed, without entering the bridge data. In the second variant, however, a model was made, to which parameters of the analysed bridge were introduced, and calculations of ordinates of the water table in the riverbed were carried out, taking into account the geometric parameters of the bridge in question. Due to the lack of historical data regarding filling (wetted perimeter) and flow rates in the area of the analysed bridge, it was not possible to calibrate the developed models. These models were built in accordance with the stages presented in by Książek et al. [2010], which included: the introduction of the delineated direction of the riverbed along with cross-sections and the bridge structure, determination of the roughness coefficient of the riverbed, introduction of hydrological data, determination of boundary conditions (uniform boundary conditions were introduced for all of the analysed cross-sections assuming critical depth conditions), determination of coefficient values for the calculations of the bridge structure using the Hec – Ras user manual, carrying out the simulation, and visualization of results. In order to perform computer calculations in the two adopted variants, a digital terrain model of the studied section of the Kłodnica river was developed. For this purpose, data was obtained from the Centre for Geodetic and Cartographic Documentation in Warsaw, in the form of ASCII XYZ files, which were used to build a digital terrain model (NMT). The digital terrain model was generated using ESRI's ArcGIS Desktop software (time license No. EVA136188158), using three basic applications of this package: ArcCatalog, ArcMap, and ArcToolbox. The ArcCatalog application was used to manage spatial data that was used to create a digital terrain model. The ArcMap application was used to edit the entered source data. However, thanks to the ArcToolbox application, data was converted and the digital terrain model was visualized as triangular irregular networks (TIN). The data processed in this way was equipped with a uniform geographical coordinate system [PUWG 1992], in accordance with the state system of spatial references [Regulation of the Council of Ministers 2012].

With the use of flow rate curves in the determined cross-sections, the accumulation (damming) height (Δz) was calculated using the formula of Bajkowski et al. [2000], and then the ordinate of the water table of the accumulated flow in the cross-section of the bridge was calculated. For both the ordinate calculated in this way, i.e. using empirical formulas, and for the ordinate of the water table of the accumulated design flow in the cross-section of the bridge determined using the HEC-RAS model [2016], the so-called clear span reserve (Z) was calculated. The span reserve (Z) is calculated as the difference in the elevation of the floor levels of the bridge span beam, and water table in the bridge cross-section. For the Wrocławski bridge, the bridge clear span reserve (Z) was calculated as the difference in the ordinates of the keystone of the bridge span arc, and the water table of the design flow in the bridge cross-section. The elevation of the keystone of the Wrocławski bridge arch is 216.10 m a.s.l.

4. Calculation results

Based on the results of geodetic measurements, cross-sections of the Kłodnica riverbed were developed. The average gradient of the water table was determined at 1.3‰. The average roughness coefficient (n_0) for the bottom of the Kłodnica riverbed according to Ven Te Chow was assumed based on field visits, amounting to 0.03 $m^{-1.3} \cdot s$ for the bottom built of coarse sand, and then taking into account the corrections resulting from the complex nature of the riverbed and vegetation on the banks, the value of the roughness coefficient of the riverbed (n) was calculated using the Cowan method, amounting to 0.072 [Mikołajczyk 2017].

Based on the field visit and the measurements made, it was found that the height of the supporting structure of the Wrocławski bridge is 0.70 to 2.29 m above the river bottom. The total length of the bridge is 22.50 m, and its total width is 20.50 m.

Prior to the construction of the hydraulic model, verification of the cross sections was made on the basis of geodetic data collected in the field, using GstarCAD software 2017. The verification was carried out in the ArcMap environment using the "interpolate line" and "profile graph" functions together with previously prepared NMT. Cross-sections were obtained corresponding to the cross-sectional location from field studies. Then, data from field measurements of the bottom of the Kłodnica riverbed were integrated with data from the digital terrain model.

The HEC-RAS program mapped the water flow conditions corresponding to the design flow rate in the riverbed of the Kłodnica river. Based on the geodetic data, cross-sections and longitudinal profile were generated, and then simulation calculations were performed without taking into account the Wrocławski bridge, and then including the bridge. The results of calculations of the ordinates of the water table in individual cross-sections of the Kłodnica river, and in the cross-section of the Wrocławski bridge, made for the two adopted calculation variants, are given in Table 1.

Table 1. The height of water damming (Δz) and reserve (Z) in cross-section of Wrocławski bridge

Calculation method	Ordinates of the water table [m a.s.l.] in the cross-sections:					Δz [m]	Z [m]
	Above (before) the bridge		At the bridge	Below (past) the bridge			
	1–1	2–2	M–M	3–3	4–4		
According to Bajkowski et al. [2000]	215.98	215.98	215.98	215.86	214.71	0.10	0.12
According to HEC-RAS first variant	216.00	215.97	215.81	215.79	214.63	–	0.31
According to HEC-RAS second variant	216.30	216.29	216.09	215.89	214.63	–	0.01

The table also includes the height of water accumulation i.e. damming (Δz) of the design flow, and the reserve in the clear span of the Wrocławski bridge (Z) calculated according to the formula proposed by Bajkowski et al. [2000]. Table 1 does not specify the height of water accumulation (Δz) for calculations with using the HEC-RS software application, conducted in two variants, because the first variant relates to the conditions of water flow on the tested section of Kłodnica without taking into account the bridge structure, and in the second variant, only water table levels in the given cross-sections were obtained.

The accumulation of computational flow calculated in the cross-section of the bridge using the formula developed by Bajkowski et al. [2000], amounting to 10 cm, will not cause the flooding of the bridge arch keystone, because the bridge clearance – reserve of the clear span (Z) is 12 cm (see Table 1). Also the results of calculations in the HEC-RAS model in the second variant indicate that the bridge arch keystone was not flooded, however, the reserve was only 1 cm.

5. Conclusions

The results of hydraulic calculations of the water flow in the clear span of the Wrocławski bridge, made using both empirical formulas and calculations made with the help of a one-dimensional hydraulic model, showed that this bridge causes significant accumulation (damming) of the adopted design flow, the intensity of which is 100 $m^3 \cdot s^{-1}$. However, the simulation results obtained indicate that there is no risk of $Q_{1\%}$ flow of 100 $m^3 \cdot s^{-1}$ as a result of its accumulation in the cross-section of the Wrocławski bridge. This is indicated by the results of calculations of the accumulation of design flow in the cross-section of the analysed bridge, i.e. according to the methodology provided by Bajkowski et al. [2000] and according to calculations using the HEC-RAS software application in the second variant, because the ordinate of water table accumulated in cross-sections before of the bridge (cross-sections 1 and 2), and an the bridge, is smaller than the lowest elevation of the riverbanks in these cross-sections. The lowest ordinate of the riverbed crown in cross-sections above the bridge is 216.34 m a.s.l. in cross-section 1, and 216.44 m a.s.l. in section 2 and in bridge section. This means that the water table of the accumulated flow in the Kłodnica riverbed will be below the lowest ordinate of the banks' crown in these sections – by 6 and 15 cm, respectively – as shown by the ordinates determined using the HEC-RAS software application in the second variant. A different situation is presented by the ISOK data, according to which, as seen in the flood risk map of the centre of Gliwice (see Fig. 1), with a flow with probability of flooding p = 1%, the centre will be flooded up to Konarskiego street on the right bank, and with a wide belt on the left bank. However, as it results from the "flood hazard maps along with water flow velocity and water flow directions" not included in this paper, flood flows, with a probability of flooding p = 1%, cause the flood as a result Kłodnica river overflowing from its banks in its upper course through Gliwice. Confirmation and documentation of the flood wave with a peak flow greater than the one assumed in the calculations, i.e. greater than $Q_{1\%} = 100\ m^3 \cdot s^{-1}$, which does not cause flooding the keystone of the Wrocławski bridge arch, and does not cause the waters of the Kłodnica river overflowing, was the flood flow in on May 18, 2010 (Fig. 4). During this flood, the peak flow was determined for the flood wave according to the "Gliwice" water gauge, and was recorded at 105 $m^3 \cdot s^{-1}$ [Ekspertyza 2012].

The impact of the Wrocławski bridge on flooding the centre of Gliwice town was determined by Czajkowska and Osowska [2014], who developed a hydraulic model reflecting the flow of water in the riverbed and floodplains of the catchment area of the Kłodnica river, using the MIKE FLOOD software developed by the Danish Institute of Hydraulics (DHI), combining one-dimensional MIKE 11 model and two-dimensional MIKE 21. As a result of calculations of the flood wave transition with a probability of p = 0.2%, Czajkowska and Osowska [2014] determined that the greatest range of the zone will cover the centre of Gliwice from Park Chrobry to Plac Marszałka Józefa Piłsudskiego, and the water depth can reach up to 6 m in some places. This means that in the case of flood surges with a flow rate higher than the design flow $Q_{1\%}$, there is a real risk of flooding the centre of Gliwice.

Photo: B. Mikołajczyk

Fig. 4. Wrocławski bridge during the freshet on May 18, 2010

The obtained preliminary results of calculations of the accumulation of the Kłodnica river waters in the centre of Gliwice by means of a hydraulic model, for a flow with a probability of exceeding p = 1% and equal to 100 $m^3 \cdot s^{-1}$, indicate a possible need to verify the flood hazard zones of Gliwice, developed as part of the ISOK project.

References

Bajkowski S., Dąbkowski Sz.L., Jaworska B., Szuster A., Utrysko B. 2000. Światła mostów i przepustów. Zasady obliczeń z komentarzami i przykładami. Red. B. Utrysko. Instytut Badawczy Dróg i Mostów, Wrocław–Żmigród.

Centrum Ratownictwa Gliwic. 2015. http://91.217.224.183/index.php/zarzadzanie-kryzysowe/ochrona-przeciwpowodziowa/zagrozenia-powodziowe

Czajkowska A., Osowska J. 2014. Wykorzystanie oprogramowania ArcGIS Desktop i MIKE 11 do wyznaczania stref zagrożenia powodziowego. [W:] Geochemia i geologia środowiska terenów uprzemysłowionych. Red. M. Pozzi. Wydawnictwo PA NOVA. Gliwice, 220–235.

Ekspertyza dotycząca możliwych do przeprowadzenia działań hydrotechnicznych, mających na celu ochronę przed powodzią terenów położonych na obszarach granicznych Gminy Gierałtowice i Miasta Zabrze oraz w dalszym biegu rzeki Kłodnicy na terenie Miasta Gliwice. 2012. GIG Katowice, Zakład Ochrony Wód, Katowice.

HEC-RAS River Analysis System, Hydraulic Reference Manual, version 5.0. 2016. US Army Corps of Engineers, Hydrologic Engineering Center.

Klaja T., Strutyński M., Wyrębek M., Leja M., Książek L. 2007. Modelowanie numeryczne warunków przepływu wód katastrofalnych w rejonie Krakowa. Zeszyty Naukowe Uniwersytetu Przyrodniczego we Wrocławiu, III, 111–116.

Kondracki J. 2002. Geografia regionalna Polski. Wyd. 3 uzup. Wydawnictwo Naukowe PWN, Warszawa.

Książek L., Wyrębek M., Strutyński M., Strużyński A., Florek J., Bartnik W. 2010. Zastosowanie modeli jednowymiarowych (HEC-RAS, MIKE 11) do wyznaczania stref zagrożenia powodziowego na rzece Lubczy w zlewni Wisłoka. Infrastruktura i Ekologia Terenów Wiejskich, 8 (1), 29–37.

Michalec B., Tarnawski M. 2007. Analiza wpływu mostów na warunki przepływu wód wezbraniowych na przykładzie potoku Czarna Woda. Monografia PAN, T. II, Konstrukcje Budowlane i Inżynierskie. Politechnika Białostocka, 609–616.

Mikołajczyk B. 2017. Ocena wpływu mostów na warunki hydrauliczne przepływu wód wezbraniowych rzeki Kłodnicy. Uniwersytet Rolniczy w Krakowie. Praca magisterska, maszynopis.

Nocoń W., Kostecki M., Kozłowski J. 2006. Charakterystyka hydrochemiczna Kłodnicy. Ochrona Środowiska, 3, 39–44.

Osman A.A. 2006. Open Channel Hydraulics. Elsevier, Oxford.

Osowska J., Kalisz J. 2011. Wykorzystanie metody River Habitat Survey do waloryzacji hydromorfologicznej rzeki Kłodnica. Górnictwo i Geologia, 6, 3, 141–156.

Plesiński K., Radecki-Pawlik A., Michalik P. 2017. Prognozowanie zmian korytotwórczych w uregulowanym korycie rzeki Czarny Dunajec z wykorzystaniem modelu jednowymiarowego. Przegląd Naukowy – Inżynieria i Kształtowanie Środowiska, 26 (3), 346–360.

Rozporządzenie Rady Ministrów z dnia 15 października 2012 r. w sprawie państwowego systemu odniesień przestrzennych. Dz. U. z 2012 r., poz. 1247.

Studium uwarunkowań i kierunków zagospodarowania przestrzennego miasta Gliwice. 2009. Załącznik nr 1 do Uchwały Nr XXXI/956/2009 Rady Miejskiej w Gliwicach z dnia 17 grudnia 2009 r. Opracowanie pracowni urbanistycznej „Plan", Gliwice.

Tarnawski M., Michalec B. 2006. Wpływ budowli hydrotechnicznych na zdolność przepustową rzeki Czarnej Staszowskiej. Zeszyty Naukowe Akademii Rolniczej we Wrocławiu, 534, ser. Inżynieria Środowiska, XV, Wrocław, 241–248.

Wagner J., Szulik J., Kaczorowski Z., Mazurek U. 2012. Warunki hydrogeologiczne Zlewni Kłodnicy na tle mapy hydrogeologicznej Polski w skali 1 : 50 000 (jednolite części wód podziemnych nr 128 i nr 129). Górnictwo i Geologia, 7, 2, 273–286.

Mgr inż. Bartłomiej Mikołajczyk
Kozmik Projekt Bartłomiej Mikołajczyk
ul. Chopina 6, 44-100 Gliwice
e-mail: kontakt@kozmik.pl

Prof. dr hab. inż. Bogusław Michalec
Uniwersytet Rolniczy w Krakowie
Katedra Inżynierii Wodnej i Geotechniki
e-mail: rmmichbo@cyf-kr.edu.pl
ORCID: 0000-0002-0402-3416

Dr inż. Mateusz Strutyński
Uniwersytet Rolniczy w Krakowie
Katedra Inżynierii Wodnej i Geotechniki
e-mail: mateusz.strutynski@urk.edu.pl
ORCID: 0000-0002-7138-2101