

Hydrodynamic parameters diversification in the watercourse with the rapid hydraulic structures (case study of the Porębianka River, Polish Carpathians)

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ABSTRACT: In modern river training practices and philosophy one can notice coming more into use ecological friendly hydraulic structures. Those, which are especially needed for river training works, as far as expectation of Water Framework Directive is concerned, are rapid hydraulic structures (RHS). What is important, RHS in general do not stop fish and invertebrates against migrating upstream, provide natural and esthetical effects within the river channel, still working as hydraulic engineering structures.

The main aim of the research was to describe changes of values of those parameters upstream and downstream of the RHS's and to find out their influence on hydrodynamics of the stream. The study was undertaken on the Porębianka river in the Gorce Mountains, Polish Carpathians. Along this paper we described and measured some hydraulic parameters within the reach of chosen rapid hydraulic structures, which we found in the field.

Observed hydrodynamic parameters within the reach of the RHS's depend on the location of measuring point and the influence of individual part of the structure. At the same time maximum velocity does not always create the bigger shear force, because it is also depend on the velocity distribution along the hydrological profile.

KEY WORDS: hydrodynamic parameters, Rapis hydraulic structure (RHS), mountain stream

1. Introduction

The purpose of this paper is determine the hydraulic parameters in the near to the rapid hydraulic structures. We want to show the possibilities of monitoring these structures in field. Additionally, we want to show changes taking to the watercourse in near to these rapids and comparison hydraulic conditions and flow regime during the two measurement periods. This paper shows analysis of hydrodynamic parameters, such as: mean velocities, shear velocities, shear stresses, Reynolds and Froude numbers.

2. Study area

The Porębianka river is 15,4 km long. It's located in the southern part of the Poland in the Gorce Mountains (Fig. 1). It's a right-bank tributary of the Mszanka river. It begins at the Obidowa peak (1000 m a.s.l.), as the Porąbka river. In the Poręba Wielka village, the river connects with the Koninka stream (6,5 km long), creating the Porębianka river. It's the largest tributary is Konina (10,7 km long). The area of the catchment is 72 km². The width of the river channel is 1 m in the upper part and 140 m in the lower part of the catchment. The average decrease is 5,96% (Korpak 2008).



Figure 1. Location of research area

The area of the catchment is built with the Carpathian flysch. The catchment is located in the north part of the Gorce mountains in two tectonic units: the tectonic window of the Mszana Dolna town and the Magura nappe.

Hydrologic characteristics of the Porębianka river were analyzed into the gauge water at the station of the IMGW. The station existed in 1957 - 1980 and was located in the Niedźwiedź village. The observed data showed that the Porębianka river is classified typologically into the rivers of the Carpathians. The river discharge is changeable and variable according to precipitation and snowmelt. The highest of water levels are observed in April, which is caused by spring snowmelt. Then the lowest of water levels is observed in February and October. The river regime is characterized by frequent changes of water levels, considerable potential for flood and significant erosion of river banks and river bed.

At the present, the watercourse has got a narrow and one-channel. At the beginning of the XX century, the Porębianka river had a braided-channel. This change was caused by several factors, but main of all: change in use of the catchment and regulated of the channel river. Currently, there are mainly a grass land, which reduces the supply of material from hillside. Moreover, the river was made regulated, is used by the constructions of dams, rapids and drop structures. It caused increase the power unit of stream and the transport of bed material during the lower flow than earlier (Korpak 2008, Korpak et al. 2008).

3. Methods

In order to understand the working principles of the research rapid hydraulic structures (RHS), we determined several objects in the field, which was named: BK - rapids with gravel bars (central and bank bars), which were creating in near to the objects; BZ - rapids with gravel bars, which were covered with grass and small bushes.

Finally, the measurements of velocity distributions were made at four objects in several measurement points and at different depths, so as to show the near-bed velocities to determine the forces acting on the bed channel in two periods. The measurement points were selected in near to rapids in such a way that as precisely as possible to hydraulic reflect the situation of the area rapids in each of the characteristic points of the structure and also in the area of the impact.

Measurements of the instantaneous velocity were made using the hydrometric current meter OTT Nautilus 2000. This appliance can measure velocities of water in range from $0,001 \text{ m} \cdot \text{s}^{-1}$ to up $10 \text{ m} \cdot \text{s}^{-1}$. Measurements were made directly above the bottom and in specific of measurement verticals. The instantaneous velocity measurements were used to draw the velocity curve in particular measurement points. Those measurements were used to determination following parameters: mean velocities, dynamic velocities, Reynolds number, Froude number, shear stress and Shields parameter.

Shear stress was calculated based on the distribution graphs of velocities on the bottom of the stream in a semi-logarithmic system. The velocity profile V_* can be found the value of the dynamic velocity, the formula (Gordon et al. 2007):

$$V_* = \frac{a}{5,75} [m \cdot s^{-1}]$$

where:

a – slope coefficient $v = f(h)$ adopting the form of the equation $y = ax + b$ (where: x – height above the bottom of the vertical measurement; b – constant)

The calculated value of dynamic velocity was used to determine the forces acting on the bottom of the watercourse. The shear stress was calculated according to the formula:

$$\tau = \dots \cdot (V_*)^2 [N \cdot m^{-2}]$$

where:

$\dots = 1000 \text{ kg} \cdot \text{m}^{-3}$ – density of water

Then, we set the Reynolds numbers Re_{av} and Re_{max} (average and maximum for the depth in vertical measurement and grained and dynamic) according to the formula:

$$Re_{av} = \frac{v_{av} \cdot h}{\nu} [-]$$

$$Re_{max} = \frac{v_{max} \cdot h}{\nu} [-]$$

where:

v_{av} – mean velocity of water $[m \cdot s^{-1}]$

v_{max} – maximum velocity of water $[m \cdot s^{-1}]$

h – depth in the watercourse $[m]$

ν – kinetic coefficient of viscosity $[m^2 \cdot s]$

We also calculated the Froude number Fr_{av} and Fr_{max} (average, maximum and dynamic in vertical measurement) according to the formula:

$$Fr_{av} = \frac{v_{av}}{\sqrt{gh}} [-]$$

$$Fr_{max} = \frac{v_{max}}{\sqrt{gh}} [-]$$

where:

v_{av} – mean velocity of water $[m \cdot s^{-1}]$

v_{max} – maximum velocity of water $[m \cdot s^{-1}]$

h – depth in the watercourse $[m]$

g – gravity $[m \cdot s^{-2}]$

4. Results

The measurement of hydrodynamic parameters was performed in the Porębianka river at four cross-sections (BK1, BK2, BZ1, BZ2, which names are related with forming the gravel bars in near to the rapids covered with plants or not covered). The results of measurement parameters are shown in tables with their corresponding graphs.

The BK1 cross-section (Fig. 2) were located at the rapid hydraulic structure and in near influence on the watercourse by its. Below the structure was a central gravel bar. Shear stresses, Reynolds

number and Froude number were different and depend on the position at the rapid (Ślizowski and Radecki-Pawlik 2000).

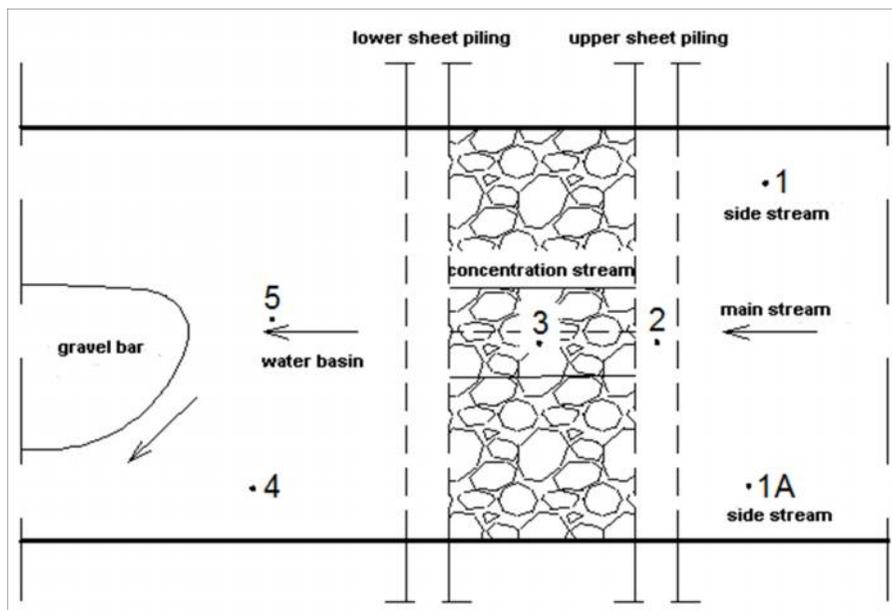


Figure 2. Arrangement of measuring points in near rapid BK1

Table 1. Hydrodynamic parameters in near rapid BK1 during Period I and II

Period I									
Points	h [m]	Re _{max} [-]	Re _{av} [-]	Fr _{max} [-]	Fr _{av} [-]	V _{av} [m · s ⁻¹]	V _{av 1cm} [m · s ⁻¹]	V _{max} [m · s ⁻¹]	‡ [N · m ⁻²]
BK1,1	0,18	7740	407	0,032	0,030	0,040	0,041	0,043	0,001
BK1,1A	0,22	83820	2987	0,259	0,216	0,317	0,299	0,381	0,064
BK1,2	0,21	149100	6200	0,495	0,464	0,666	0,620	0,710	0,144
BK1,3	0,50	460000	7833	0,415	0,382	0,847	0,783	0,920	1,024
BK1,4	0,50	8500	123	0,008	0,007	0,015	0,012	0,017	0,001
BK1,5	0,45	174600	2473	0,185	0,151	0,318	0,247	0,388	0,324
Period II									
Points	h [m]	Re _{max} [-]	Re _{av} [-]	Fr _{max} [-]	Fr _{av} [-]	V _{av} [m · s ⁻¹]	V _{av 1cm} [m · s ⁻¹]	V _{max} [m · s ⁻¹]	‡ [N · m ⁻²]
BK1,1	0,22	40920	1140	0,127	0,091	0,134	0,114	0,186	0,064
BK1,1A	0,25	172500	4667	0,441	0,350	0,549	0,467	0,690	0,676
BK1,2	0,35	185500	4100	0,286	0,255	0,473	0,410	0,530	0,324
BK1,3	0,15	225000	13700	1,237	1,155	1,402	1,370	1,500	0,361
BK1,4	0,40	280000	4633	0,353	0,290	0,574	0,463	0,700	1,225
BK1,5	0,35	287000	4667	0,443	0,359	0,644	0,467	0,820	3,025

where:

h – depth in the watercourse,

Re_{av}, Re_{max} – Reynolds number, respectively average and maximal

Fr_{av}, Fr_{max} – Froude number, respectively average and maximal

V_{av}, V_{av 1cm}, V_{max} – velocity of water, respectively average, average above 1 cm above the bed channel and maximal

‡ – shear stresses acting on the bed channel

In the Period I of measurement (Tab. 1), the highest values of average velocities $V_{av} = 0,666 \text{ m} \cdot \text{s}^{-1}$ and $V_{av} = 0,847 \text{ m} \cdot \text{s}^{-1}$ were noticed respectively at point BK1,2 (upper sheet piling) and BK1,3 (drop plate of rapid) in the central of part structure. The lowest values of average velocities $V_{av} = 0,015 \text{ m} \cdot \text{s}^{-1}$ and $V_{av} = 0,040 \text{ m} \cdot \text{s}^{-1}$ were noticed respectively at point BK1,4 and BK1,1 in the side of channel. The maximum value of shear stress $\tau = 1,024 \text{ N} \cdot \text{m}^{-2}$ was noticed at point BK1,3 (drop plate of rapid) for depth $h = 0,50 \text{ m}$. The highest value of shear velocity $V_* = 0,032 \text{ m} \cdot \text{s}^{-1}$ was also noticed at point BK1,3. The value of Reynolds numbers were noticed $Re_{av} = 407$ and $Re_{av} = 123$ at points BK1,1 and BK1,4, so the laminar conditions were observed at these points. At other points of the BK1 cross-section had a turbulent stream. The subcritical conditions were at all points, where Froude numbers $Fr_{av} < 1$ was noticed.

In the Period II of measurement (Tab. 1), the maximum values of average velocity $V_{av} = 1,402 \text{ m} \cdot \text{s}^{-1}$ was noticed at point BK1,3 (drop plate of rapid) and was higher than at some point during the first period. At other point, the values of average velocities were between $V_{av} = 0,134 - 0,359 \text{ m} \cdot \text{s}^{-1}$. The highest values of shear stress was below the rapid, was noticed $\tau = 3,025 \text{ N} \cdot \text{m}^{-2}$ at point BK1,5 for depth $0,35 \text{ m}$. The high values of shear stress was also observed $\tau = 1,225 \text{ N} \cdot \text{m}^{-2}$ at point BK1,4 in the left side of channel and below the rapid. At other points, shear stresses were in range $\tau = 0,064 - 0,676 \text{ N} \cdot \text{m}^{-2}$. The high values of shear velocities $V_* = 0,035 \text{ m} \cdot \text{s}^{-1}$ and $V_* = 0,055 \text{ m} \cdot \text{s}^{-1}$ were noticed respectively at point BK1,4 and BK1,5. The lowest values of Reynolds number $Re_{av} = 1140$ was noticed at point BK1,1, so there was laminar conditions in the channel. At other points were observed turbulent conditions. Only at point BK1,3 (drop plate of rapid) value of Froude number $Fr_{av} = 1,155$ was noticed, so there was supercritical conditions in the object. The subcritical conditions were at other points, where Froude numbers $Fr_{av} < 1$ was noticed.

The BK2 cross-section (Fig. 3) were located at the rapid hydraulic structure and in near influence on the watercourse by its. Shear stresses, Reynolds number and Froude number were different and depend on the position at the rapid.

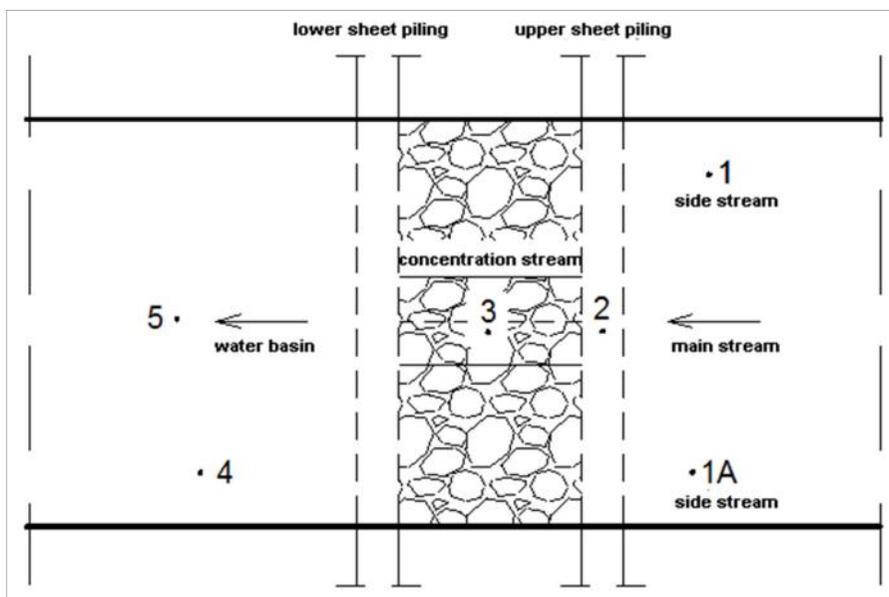


Figure 3. Arrangement of measuring points in near rapid BK2

Table 2. Hydrodynamic parameters in near rapid BK2 during Period I and II

Period I									
Points	h [m]	Re _{max} [-]	Re _{av} [-]	Fr _{max} [-]	Fr _{av} [-]	V _{av} [m · s ⁻¹]	V _{av 1cm} [m · s ⁻¹]	V _{max} [m · s ⁻¹]	τ ₁ [N · m ⁻²]
BK2,1	0,32	58560	1573	0,103	0,090	0,159	0,157	0,183	0,029
BK2,1A	0,10	25800	2167	0,260	0,236	0,234	0,217	0,258	0,031
BK2,2	0,22	242000	9633	0,749	0,692	1,017	0,963	1,100	0,289
BK2,3	0,06	84000	13500	1,825	1,786	1,370	1,350	1,400	0,100
BK2,4	0,38	19760	260	0,027	0,016	0,031	0,026	0,052	0,004
BK2,5	0,55	291500	1747	0,228	0,140	0,325	0,175	0,530	1,764
Period II									
Points	h [m]	Re _{max} [-]	Re _{av} [-]	Fr _{max} [-]	Fr _{av} [-]	V _{av} [m · s ⁻¹]	V _{av 1cm} [m · s ⁻¹]	V _{max} [m · s ⁻¹]	τ ₁ [N · m ⁻²]
BK2,1	0,28	69440	1403	0,150	0,112	0,186	0,140	0,248	0,169
BK2,1A	0,19	57000	2293	0,220	0,191	0,261	0,229	0,300	0,100
BK2,2	0,25	275000	8267	0,702	0,634	0,993	0,827	1,100	2,025
BK2,3	0,50	572000	10407	0,517	0,487	1,078	1,041	1,144	0,144
BK2,4	0,46	32660	620	0,033	0,030	0,064	0,062	0,071	0,001
BK2,5	0,60	378000	3653	0,260	0,201	0,487	0,365	0,630	1,444

In the Period I of measurement (Tab. 2). The highest value of average velocities $V_{av} = 1,017 \text{ m} \cdot \text{s}^{-1}$ and $V_{av} = 1,370 \text{ m} \cdot \text{s}^{-1}$ were noticed respectively at point BK2,2 and BK2,3, so maximum velocities were observed in the central of part structure. The lowest value of average velocities $V_{av} = 0,031 \text{ m} \cdot \text{s}^{-1}$ was noticed at point BK2,4 in the side of channel. At other point, average velocities were in range $V_{av} = 0,159 - 0,325 \text{ m} \cdot \text{s}^{-1}$.

The maximum value of shear stress were noticed $\tau = 1,764 \text{ N} \cdot \text{m}^{-2}$ for depth $h = 0,55 \text{ m}$ at point BK2,5, so were observed in the central of channel and below the rapid. At the some point, maximum value of shear velocity was also observed $V_* = 0,042 \text{ m} \cdot \text{s}^{-1}$. The laminar conditions were observed at the left side of channel and below the rapid, where Reynolds number was noticed $Re_{av} = 260$. At other places of channel were turbulent conditions. Froude number was noticed $Fr_{av} = 1,786$ at the central of rapid (at point BK2,3), so was observed turbulent conditions. At other points were observed laminar conditions ($Fr_{av} < 1$).

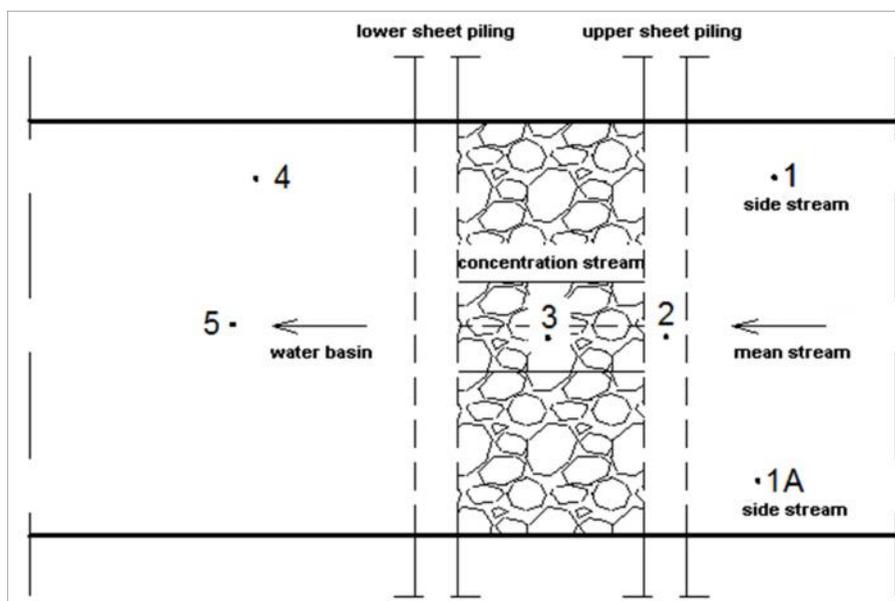
In the Period II of measurement (Tab. 2), the maximum value of average velocity $V_{av} = 1,078 \text{ m} \cdot \text{s}^{-1}$ was noticed at point BK2,3 (drop plate of rapid). At point BK2,4, value of velocity was also lowest at the watercourse. At other places of the watercourse, average velocities were higher than during the first period, its values were between $V_{av} = 0,186 - 0,993 \text{ m} \cdot \text{s}^{-1}$.

The highest values of shear stresses were at point BK2,2 (upper sheet piling) and at point BK2,5 (at the central of channel and below the rapid), were noticed respectively $\tau = 2,025 \text{ N} \cdot \text{m}^{-2}$ and $\tau = 1,444 \text{ N} \cdot \text{m}^{-2}$. At other places of the watercourse, shear stresses were also higher than during the first period. The highest value of shear stress was noticed $V_* = 0,044 \text{ m} \cdot \text{s}^{-1}$ at point BK2,2, so its value was also higher than at the first period. Turbulent conditions were observed in the watercourse. Froude numbers were noticed $Fr_{av} < 1$ in the river channel, so at the watercourse was observed subcritical conditions.

The BZ1 cross-section were located at the rapid hydraulic structure and in near influence on the watercourse by its (Fig. 4). Shear stresses, Reynolds number and Froude number were different and depend on the position at the rapid.

Table 3. Hydrodynamic parameters in near rapid BZ1 during Period I and II

Period I									
Points	h [m]	Re _{max} [-]	Re _{av} [-]	Fr _{max} [-]	Fr _{av} [-]	V _{av} [m · s ⁻¹]	V _{av 1cm} [m · s ⁻¹]	V _{max} [m · s ⁻¹]	‡1 [N · m ⁻²]
BZ1,1	0,20	33400	1500	0,119	0,111	0,156	0,150	0,167	0,004
BZ1,1A	0,10	15100	1227	0,152	0,135	0,134	0,123	0,151	0,016
BZ1,2	0,21	170100	7500	0,564	0,540	0,776	0,750	0,810	0,064
BZ1,3	0,07	34300	3493	0,591	0,488	0,405	0,349	0,490	0,784
BZ1,4	0,49	12250	57	0,011	0,005	0,012	0,006	0,025	0,004
BZ1,5	0,85	255000	1623	0,104	0,079	0,227	0,162	0,300	0,624
Period II									
Points	h [m]	Re _{max} [-]	Re _{av} [-]	Fr _{max} [-]	Fr _{av} [-]	V _{av} [m · s ⁻¹]	V _{av 1cm} [m · s ⁻¹]	V _{max} [m · s ⁻¹]	‡1 [N · m ⁻²]
BZ1,1	0,12	38880	2413	0,299	0,258	0,280	0,241	0,324	0,121
BZ1,1A	0,12	37440	2740	0,288	0,267	0,290	0,274	0,312	0,064
BZ1,2	0,29	240700	6433	0,492	0,430	0,726	0,643	0,830	0,625
BZ1,3	0,05	45500	6000	1,299	1,045	0,732	0,600	0,910	4,356
BZ1,4	0,20	25400	957	0,091	0,080	0,111	0,096	0,127	0,016
BZ1,5	0,60	192000	1637	0,132	0,093	0,226	0,164	0,320	0,361

**Figure 4.** Arrangement of measuring points in near rapid BZ1

In the Period I of measurement (Tab. 3), values of average velocities were in range $V_{av} = 0,134 - 0,776 \text{ m} \cdot \text{s}^{-1}$ for depth $h = 0,07 - 0,85 \text{ m}$. The lowest value of average velocity was noticed $V_{av} = 0,012 \text{ m} \cdot \text{s}^{-1}$ at the side of channel (at point BZ1,4). The highest value of shear stresses were observed on the drop plate of rapid and below the rapid (at points BZ1,3 and BZ1,5), so were noticed respectively $\tau = 0,784 \text{ N} \cdot \text{m}^{-2}$ and $\tau = 0,624 \text{ N} \cdot \text{m}^{-2}$. At other points, values of velocities were in range $\tau = 0,004 - 0,064 \text{ N} \cdot \text{m}^{-2}$. Laminar conditions were observed only at point BZ1,4, value of Reynolds number was noticed $Re_{av} = 57$. Subcritical conditions were observed at the watercourse.

In the Period II of measurement (Tab. 3), values of average velocities were as similar as during the first period of measurement and were noticed in range $V_{av} = 0,111 - 0,732 \text{ m} \cdot \text{s}^{-1}$. The very high value of shear stress was noticed $\tau = 4,356 \text{ N} \cdot \text{m}^{-2}$ on the drop plate of rapid (at point BZ1,3). At other places of the watercourse, values of shear stresses were lower than at point BZ1,3. Additionally, shear stresses were lower than at the first period of measurement, were noticed in range $\tau = 0,016 - 0,625 \text{ N} \cdot \text{m}^{-2}$. At point BZ1,3 were the highest value of shear velocity and were noticed $V_* = 0,066 \text{ m} \cdot \text{s}^{-1}$. At the channel river were observed turbulent conditions. Only at point BZ1,3 (drop plate of rapid) were observed supercritical conditions ($Fr_{av} = 1,045$), at other places ($Fr_{av} < 1$) were subcritical conditions.

The BZ2 cross-section (fig. 5) were located at the rapid hydraulic structure and in near influence on the watercourse by its. Shear stresses, Reynolds number and Froude number were different and depend on the position at the rapid.

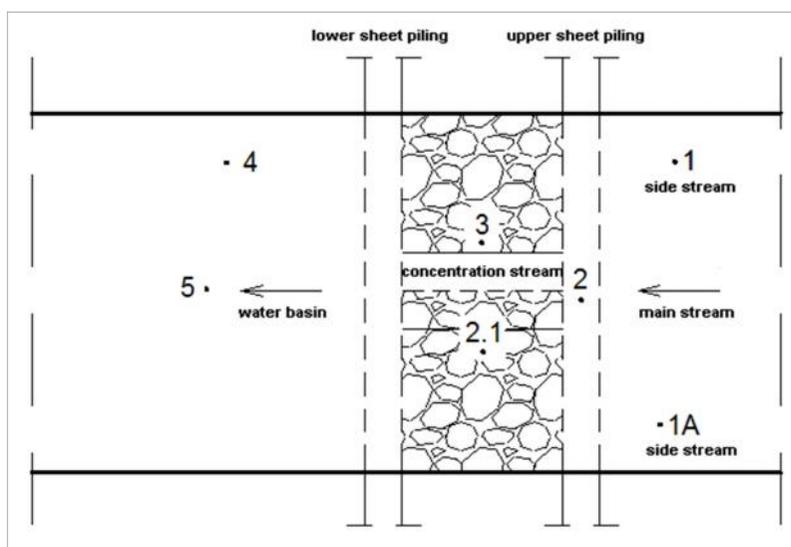


Figure 5. Arrangement of measuring points in near rapid BZ2

Table 4. Hydrodynamic parameters in near rapid BZ2 during Period I and II

Period I									
Points	h [m]	Re_{max} [-]	Re_{av} [-]	Fr_{max} [-]	Fr_{av} [-]	V_{av} [$\text{m} \cdot \text{s}^{-1}$]	$V_{av 1cm}$ [$\text{m} \cdot \text{s}^{-1}$]	V_{max} [$\text{m} \cdot \text{s}^{-1}$]	τ [$\text{N} \cdot \text{m}^{-2}$]
BZ2,1	0,11	14190	660	0,124	0,088	0,091	0,066	0,129	0,064
BZ2,1A	0,11	33440	2210	0,293	0,243	0,252	0,221	0,304	0,121
BZ2,2	0,16	171200	9133	0,854	0,776	0,972	0,913	1,070	0,400
BZ2,3	0,10	57000	2840	0,575	0,379	0,375	0,284	0,570	2,025
BZ2,4	0,30	44400	893	0,086	0,067	0,115	0,089	0,148	0,064
BZ2,5	0,50	139000	1497	0,126	0,094	0,209	0,150	0,278	0,324
Period II									
Points	h [m]	Re_{max} [-]	Re_{av} [-]	Fr_{max} [-]	Fr_{av} [-]	V_{av} [$\text{m} \cdot \text{s}^{-1}$]	$V_{av 1cm}$ [$\text{m} \cdot \text{s}^{-1}$]	V_{max} [$\text{m} \cdot \text{s}^{-1}$]	τ [$\text{N} \cdot \text{m}^{-2}$]
BZ2,1	0,30	15900	407	0,031	0,027	0,046	0,041	0,053	0,004
BZ2,1A	0,09	53100	5000	0,628	0,581	0,546	0,500	0,590	0,169
BZ2,2	0,29	179800	1600	0,368	0,197	0,332	0,160	0,620	3,136
BZ2,3	0,12	103200	4867	0,793	0,615	0,668	0,487	0,860	2,916
BZ2,4	0,38	120840	2220	0,165	0,136	0,263	0,222	0,318	0,169
BZ2,5	0,49	303800	3593	0,283	0,204	0,446	0,359	0,620	0,961

In the Period I of measurement (Tab. 4), the values of average velocities were in range $V_{av} = 0,091 - 0,972 \text{ m} \cdot \text{s}^{-1}$; the highest value was observed at point BZ2,2, while the lowest values was noticed at point BZ2,1. The very high values of shear stress was noticed $\tau = 2,025 \text{ N} \cdot \text{m}^{-2}$ for shear velocity $V_* = 0,045 \text{ m} \cdot \text{s}^{-1}$ at point BZ2,3 (drop plate of rapid). At other points were noticed between $\tau = 0,064 - 0,400 \text{ N} \cdot \text{m}^{-2}$. Reynolds numbers and Froude numbers define conditions acting at the watercourse, where were observed only turbulent ($Re_{av} > 500$) and subcritical ($Fr_{av} < 1$) conditions.

In the Period II of measurement (Tab. 4), the values of average velocities were a bit lower than during at first period. Average velocities were noticed in range $V_{av} = 0,046 - 0,668 \text{ m} \cdot \text{s}^{-1}$ (the highest value at point BZ2,3 and the lowest value at point BZ2,1). However, values of shear stresses were a lot higher than at the first period. The very high values of shear stresses were noticed $\tau = 3,136 \text{ N} \cdot \text{m}^{-2}$ and $\tau = 2,916 \text{ N} \cdot \text{m}^{-2}$ respectively at point BZ2,2 and BZ2,3. The highest shear velocities were noticed $V_* = 0,056 \text{ m} \cdot \text{s}^{-1}$ and $V_* = 0,054 \text{ m} \cdot \text{s}^{-1}$ at the same points. At other places of channel river, values were similar to last period of measurement and were noticed in range $\tau = 0,004 - 0,961 \text{ N} \cdot \text{m}^{-2}$. At side of the channel and above the rapid were observed laminar conditions. At other places of the watercourse were turbulent conditions. At all measurement points of the watercourse were observed subcritical conditions.

5. Conclusions

The conclusions with performed researches are following:

1. Hydrodynamic parameters in near to the rapid hydraulic structures depend on the location of the measurement points in relation to particular elements of the rapids. Additionally, these parameters also depend on the water level in the channel river.
2. The highest value of velocities don't cause creating the highest of force, which acting on the bed of the watercourse, because it is rather related to the water level of the channel.
3. In near to the structures, hydrodynamic parameters were different, what cause increasing various river-fauna (Kłonowska-Olejnik, Radecki-Pawlik 2000).
4. The highest values of velocities and shear stresses were observed at the drop plate of rapids.
5. The values of mean velocities, shear velocities and shear stresses were similar both above and below the rapids, which means that the rapids are working well (Ślizowski 1993; Ślizowski, Radecki-Pawlik 1998).

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