Original Research

Dynamics of Water Flow on Degraded Sectors of Polish Mountain Stream Channels

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Received: 22 March 2008
Accepted: 31 March 2009

Abstract

Our study is aimed at determining the hydrodynamic changes of mountain stream channels caused by degradation that was initiated by uncontrolled mining of bed material. The study was conducted on Mszanka and Targaniczanka streams in which the collected data included: longitudinal profiles, cross-sections of the channels, the geometry of bed forms and analysis of particle composition of the bed material. The results show that hydrodynamic parameters have changed downstream from the studied sectors and along the cross-sections. Bed degradation also was linked to bank erosion, which intensified morphological changes of channels effecting the spatial distribution of flow velocity, shear stresses and stream power. The investigation also demonstrated that the bedload movement was in accordance with channel changes and more sediments were deposited than transported along the studied area. Finally, local aggradation and unstable channel capacity were observed.

Keywords: riverbed degradation, water flow, stream power, morphological changes

Introduction

A stable river channel with hydrodynamic balance preserves ecological continuity. The bed of such a channel has a characteristic armouring layer that may appear due to the sorting activity of the water stream. After the small fractions of bed sediments are washed out, the biggest grains form a layer at the bottom of the channel, which needs stronger stream power to trigger bedload transport. The lack of armouring is indicative of unstable channel sectors and its degradation. In consequence, the capacity of the channel decreases and there appears an imminent danger of flood in urbanized areas. In the period between flood events, water does not flow through whole width of the channel, but through narrow streams. In consequence, local discontinuities of the water stream appear. The shallow flows cause rapid warming of the water in summer and freezing of the entire surface of the cross-section in winter. They are not favourable for fish migration [1]. Conditions like that cause ecological discontinuity of the stream. The aim of our research was to determine the changes in the dynamics of flow on the degraded sectors of the mountain stream channels. On a short sector of the stream, too big velocity gradients, shear stresses and stream power may cause irreversible morphological changes that expand up and down the channel even during small freshet events.

Degradation of mountain stream channels occurs mostly due to irregular water flow and unbalanced sediment transport [2]. One of the causes modifying this hydrodynamic balance is a flood wave that rapidly increases the transport capacity of bedload sediments [3, 4]. Depending on the duration of the freshet, the process either displaces down the river or degrades locally the stream cross-section. Another contribution to the degradation process is digging

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of the gravel bed material [5] and levelling of the bottom surface. These causes are usually accompanied by degradation by bank erosion. With regard to its intensity of occurrence and threats associated with it, it has been the subject of numerous studies [6-9]. In degraded sectors of the channel, the changes of hydrodynamic conditions intensify the morphological processes. The effects of this degradation can be visualized by a change in channel geometry – shape of cross-section and longitudinal profile – which is the consequence of reciprocal relations among such characteristics as: water flow, water depth, channel width and hydraulic slope [10-12].

In order to improve conditions of the degraded sectors and to ensure ecological continuity, it is necessary to define the changes appearing in the dynamics of flows. In order to appraise dynamic changes caused by freshet degradation in mountain stream channels, studies were carried out on Targaniczanka and Mszanka streams (Poland). The streams flow across urban areas, and processes that take place in them are representative of the other Carpathian channels. In these sectors local changes in the bed appear, local scouring of the bed material is being exploited and training works are carried out to increase channel capacity.

Field measurements included characteristics that allow determination of the level of degradation in regards to bedload transport.

Material and Methods

Description of the Studied Objects

Targaniczanka Stream is a left bank tributary of the Wieprzówka River (Fig. 1). The whole basin of the stream (22.9 km^2) lies in the Beskid Mały Mountains of the Polish Carpathians. The mean annual rainfall in the years 1951-70 measured at Andrychow station was 898 mm and in the period 1992-2002 it was 889 mm. For the most part the catchment is overgrown by forest (60%), agricultural land cover 30% and remaining part is urbannized.

The research reach was situated at the outlet of the watershed and closes a basin of A = 16.76 km^2 area. The distance from the springs to the studied place is L = 8.25 km. The investigated L_1 = 358 m long sector was located in the town of Sułkowice on the road bridge situated on the local road. In this part of the stream, hydrotechnical structures were located and measurements of longitudinal profiles, cross-sections of the channel and of granulometric composition of the bed material were carried out. The size distribution of the sediment was measured by sieving.

The sections differ in size and shape of the channel. The cross-sections in which the water meanders are 25-30 m wide. Pools and bars of height reaching 1 m are overgrown with vegetation. In the region of the bridge, vegetation disappears and this may indicate frequent bedload transport. The Targaniczanka bed is covered with big grain bed material, which mainly consists of boulder and gravel fractions. The biggest diameter of the grain taken from the sample was 0.26 m.

The catchment area (174,13 km^2) of the Mszanka Stream is in the Beskid Wyspowy Mt. of the Polish Carpathians. Annual rainfall in the investigated area was equal to 979 mm. The studied sector located in the town of Mszana Górna is situated at L = 6.2 km upstream the estuary to the Raba River and closes a basin of 61 km^2 area. The flood events in June 1995 for which the discharge reached Q_{max}=39.9 m^3·s^{-1} and stream level elevation h = 1.2 m was so rapid that the intensive bedload transport changed the morphology of the channel. The August-September freshet in 1996 was smoother (Q_{max}=23.8 m^3·s^{-1}), but the two-month lasting flows (Q = 5.0-15.0 m^3·s^{-1}) evoked significant channel modification.

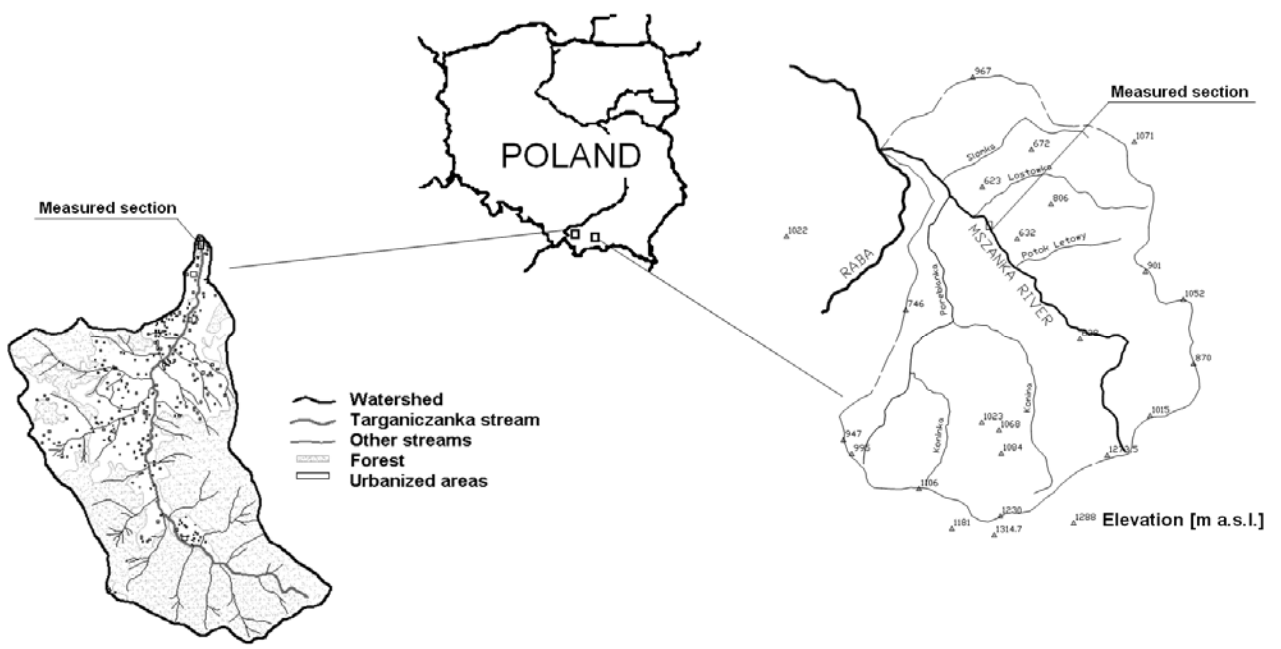

Fig. 1. Location map of the Targaniczanka and Mszanka streams, Poland.

Experimental Procedure

Field measurements were performed after flood events in both streams and included longitudinal profiles of the degraded parts of the channel, cross-sections and grain-size composition of the bed material. An 80 kg sample was put through a set of sieves in order to determine the weight particular fractions. Based on the results, grain-size distribution curves were drawn and mean diameter dm was calculated. As results of survey measurements, bed slope, water surface slope and bed configuration along the studied sector were obtained.

These data were sufficient to describe the river channel dynamics and enabled us to determine the changes of hydraulic and morphological conditions. The geometry of the bed forms is generated by stream power:

$$\omega = \tau \cdot v \quad [N \cdot m^{-1} \cdot s^{-1}]$$

Local shear stresses

$$\tau = \gamma \cdot h \cdot J \quad [N \cdot m^{-2}]$$

...and their dimensionless form

$$f = \tau/(\gamma_s - \gamma) \cdot d$$

...were used for calculating bedload transport intensity according to the Meyer-Peter and Mueller modified equation [13]. The entrainment function or hidding function for grains has the form:

$$f_i = 0.032\ (d_i/d_{50})^{-0.90}$$

In the above equations: γ, γ_s - specific weight of water and sediment respectively, h – water depth, J – slope of energy line (or I_b – slope of bottom), f_i – dimensionless shear stresses (Shield's parameter) for sediment fraction of diameter di. Moreover, with the computer program HEC-RAS, distribution of water velocity and stresses in studied cross-sections were calculated.

Procedure HEC-RAS [14] was used to perform one-dimensional calculations of hydraulic parameters and water surface level under steady water flow conditions. The governing equation includes one-dimension energy equation (Bernoulli eq.), where energy losses are evaluated by friction Manning's equation

$$v = 1/n \cdot R_h^{2/3} \cdot S_f^{1/2}$$

...where: n – Manning roughness coefficient, R_h – hydraulic radius, $R_h = A/U_z$, U_z – wetted perimeter, A – cross-section area, S_f – friction gradient.

Rapidly varied flow regime (hydraulic jumps, hydraulics of bridge) was simulated using the momentum equation.

The resistance to flow depends on structure of the river bed. In order to take into consideration the influence of granulometry of river bed on the roughness coefficient, the following equations were utilized: Strickler $1/n = 21/d_m^{1/6}$, which was transformed by Meyer-Peter and Mueller, to $1/n = 26/d_{90}^{1/6}$ equations to express the roughness due to a nonuniform bed material.

Results

Mszanka Stream

Results showed that freshets triggered morphological changes in the channel of the stream. Indeed, in the year 1995, cross-sections in the sector of length L=200 m changed their shape from an asymmetric triangle of water level width at low stages (B=2 m to B=10 m), at high water stages to a trapezoid cross-section of width ranging from 17 to 20 m. Along the studied sector, deposited sediments are found almost on the whole width of the channel as bar forms. Local digging of gravel created cavities in the bed and, consequently, its degradation. Fig. 2 shows a longitudinal profile

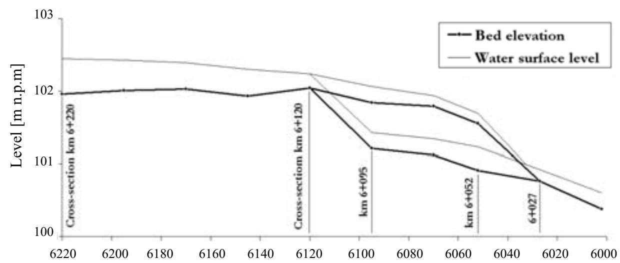

Fig. 2. The longitudinal profile of the research reach of the Mszanka Stream, October 1996.

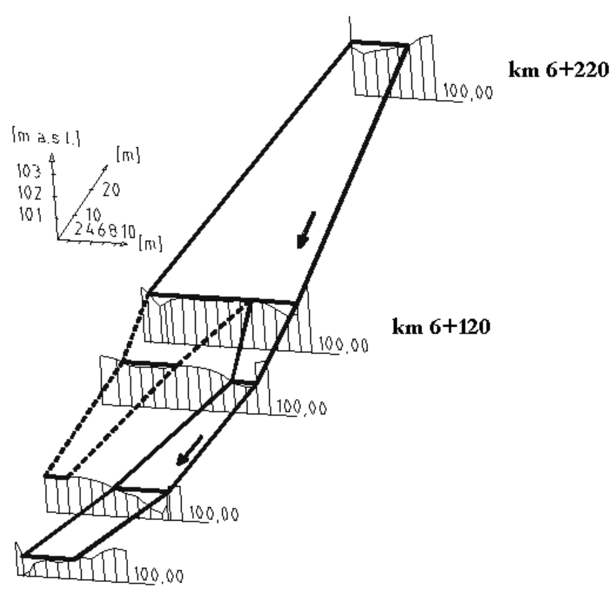

Fig. 3. 3D view of the research reach of the Mszanka Stream, October 1996. The solid line represents the water surface level borders in the main stream. The broken line represents the water surface level for the secondary stream.

measured in October 1996, where two fast-running water streams are clearly visible, for example between km 6+095 and km 6+120. On such a short distance, local bed slope (I) changes from 0.004 to 0.025, whereas the regular gradient (I) was 0.0062.

Cross-sections measured in 1996 associated with this profile were shown in Fig. 3. The stream is divided in two parts from km 6+120 to km 6+027, where the main stream is on the left bank and a small and shallow right bank stream formed. The riverbed lowered and so did the cross-sections and the bar that was carried away. This was confirmed by measurements of grain-size distribution of sediment, which showed that even the mean diameter was unchanged (d_{50} = 0.044 m), diameters of bigger fractions decreased from d_{90} = 0.109 m to d_{90} = 0.077 m. This indicates that migration of the bars proceeded by washing out smaller fractions that were deposited downstream of the studied sector of Mszanka Stream.

Concomitantly with migration of the bar, migration of banks also took place. After the first flood events, erosion on the right bank appeared and during the last studied events the left bank showed evidence of erosion and this process exceeded in the investigated sector.

The mean diameter dm in the sector of Mszanka Stream was between 0.061 and 0.043 m, whereas in the stabilized sector it was 0.073 m. The standard deviation of granulation curve $\delta = (d_{84}/d_{16})^{0.5}$ was bigger than 1.3 (from 2.61 to 2.40), which indicates a higher percentage of small fractions. This bed material is most easily transported by the flow. Roughness coefficient calculated according to Strickler equation was n=0.027.

Targaniczanka Stream

In 2004, measurements were performed on the sector of the stream where gravel is dug up and the stream bottom is levelled. Geodetic surveys were carried out in 20 cross-sections. Distances between them varied from 5 m to 30 m and the average channel width was about b = 20 m. The longitudinal profile of that sector showed that the local slope changed three times, adopting respective values: I_1=0.0142, I_2=0.0166, I_3=0.0298 and I_4=0.0119, whereas the value of the levelled bed slope was I_b=0.0144. Along the research reach, the main stream flows bends separating masses of accumulated sediment in layers reaching about 1 m depth. The bed material consisted of coarse-grained gravels and boulders of a diameter d_{50}=0.05 m in the stream and d_{50} = 0.027 m on the bars. Whereas the value of diameter d_{90} in the stream was 0.20 m, various values found on the bars ranged from d_{90} = 0.09 m to d_{90} = 0.15 m.

Table 1. Flow characteristics in selected cross-sections, Targaniczanka Stream, 2006.

Cross-section	Bed width b [m]	Bankfull discharge Q_{bmax} [$m^3 \cdot s^{-1}$]	Water surface width B [m]
2+736	24.3	260.0	35.8
2+609	19.2	82.80	23.7
2+547	17.0	66.4	27.4

Flow probability appearances for the partial basin are calculated according to the Punzet empiric formula [15], which has a regional character and is very useful for uncontrolled mountain watersheds. The discharges of 50%, 10%, 1%, and 0.1% annual exceedance probability are as follows: $Q_{50\%}$ = 7.90 $m^3 \cdot s^{-1}$, $Q_{10\%}$ = 30.57 $m^3 \cdot s^{-1}$, $Q_{1\%}$ = 66.41 $m^3 \cdot s^{-1}$, and $Q_{0.1\%}$ = 100.40 $m^3 \cdot s^{-1}$ [16].

In 2006, after the passage of a discharge about $Q_{1\%}$ (in August 2005), a geodetic survey was conducted on a sector up to 480 m long, which included the sector studied in 2004. For 21 cross-sections, the longitudinal profile and the bed granulometric composition were measured. The bed slope changes from I_1 = 0.015 to I_2 = 0.021 and to I_3 = 0.009 were observed. The value of the levelled bed slope was I_b = 0.016. Along the whole length of the sector morphological changes were observed as illustrated in Fig. 4. In the cross-section km 2+547, the channel width was 17 m, water surface level width at lower water level H = 0.15 m was B = 2.7 m. At the bank discharge (Q_{max} = 66.40 $m^3 \cdot s^{-1}$) the water surface was 27.4 m. The width of the bed and maximum discharge in cross-sections km 2+609 and km 2+736 were b = 19.2 m and b = 24.3 m, and Q_{max} = 82.80 $m^3 \cdot s^{-1}$ and Q_{max} = 260.0 $m^3 \cdot s^{-1}$ (respectively), for which water surface width was, respectively B = 23.7 m and B = 35.8 m. The thickness of the sandbar situated in cross-section km 2+609 and section km 2+736 are 0.4 m and 0.6 m, respectively.

Mean diameters dm and standard deviation δ of sieve curve for samples collected from the water stream were from d_m=0.071 m (δ=3.71) to d_m=0.055 m (δ=2.7) for samples collected from the bars, and from d_m=0.042 m (δ=3.02) to d_m=0.048 m (δ=3.12).

Basin on granulometric composition of the bedload values for roughness coefficient of the main channel bed were calculated. The following results were obtained: by Strickler (d_m=0.055 m) n=0.029, by Meyer-Peter and Mueller equation (d_{90}=0.136 m) n=0.027. For further calculations n=0.029 (main channel) and n=0.06 (floodplain) were taken.

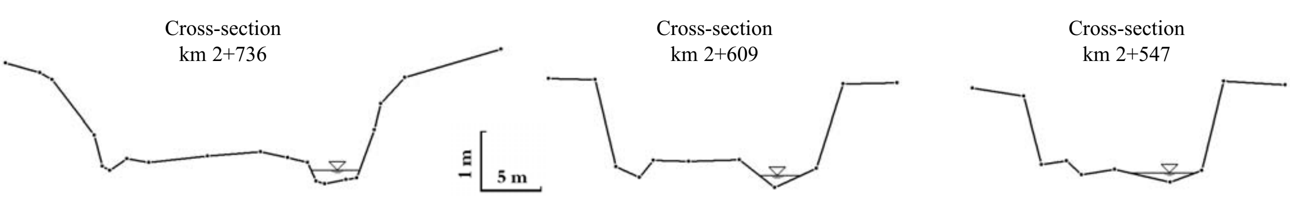

Fig. 4. Examples of the cross-section of Targaniczanka Stream, 2006.

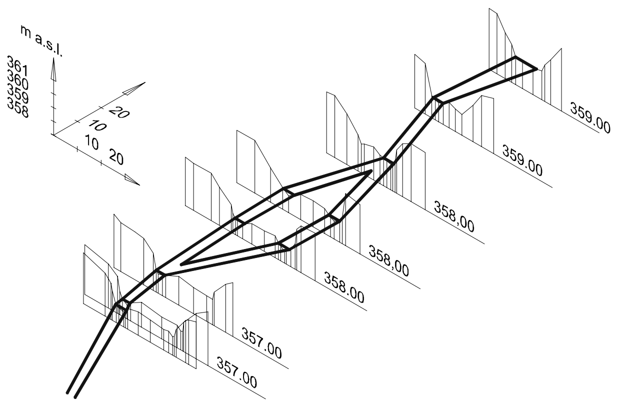

Fig. 5. 3D view of upper part of the research reach of Targaniczanka Stream, 2006.

Morphological changes in cross-sections along the stream are shown in Fig. 5. It is noticeable that, from the upper part of the sector, the main stream flows close to the right bank, then changes its direction and flows along the left bank. Then it divides into two parts for about 80 m and again is reunited into one stream flowing along the right bank and returning again to the left bank. In the lower part of the sector, the water stream behaves in a similar way, flowing alternately along the right and left banks.

Granulometric composition of the sediment was determined in 6 points along the studied sector and showed evidence of irregularity in bedload transport. Indeed, diameter d_{50} changed among the sampled points from d_{50} = 0.027 m to d_{50} = 0.048 m and the diameter d_{90} = 0.08 – 0.18 m. It could be stated that nearer the bridge the higher percentage of small fractions (d_i<0.02 m) increased from 29.7% to 42.0%.

Discussion of Results

The riverbed configuration as the array of bed forms, or absence thereof, is generated by the flow [17-19]. It is associated with bed roughness and resistance to flow [20-23]. Generally speaking, the depth of the flow relates to roughness and may affect the velocity field. Morphological changes observed in measurements found reflection also in variable values of such quantities as velocity and shear stress. In every cross-section there, of these quantities was calculated.

The calculations were made for flows occurring during a freshet event in 1996 in Mszanka Stream. Fig. 6 shows sections km 6+220 and km 6+120 for a discharge of 23.8 $m^3 \cdot s^{-1}$.

The means of each parameter calculated for a freshet event with a discharge of 23.8 $m^3 \cdot s^{-1}$ are listed in Table 2. For each parameter, the values of each subsection also showed and justified the fact that the mean values are insufficient to explain morphological changes of the channel. Similar to velocity, water depth also changes, e.g. in cross-section km 6+027 for discharge Q = 23.8 $m^3 \cdot s^{-1}$, water depth varied from h = 0.12 m to h = 0.89 m, with an average of h_m = 0.43 m. Analogous changes were observed in other cross-sections, meaning also variability for shear stresses and stream power.

On the studied sector of Mszanka Stream, the stream power increased and decreased, alternately changing even by an order of magnitude at a given discharge. This caused irregular transport of sediments on the whole length of the sector. In cross-section km 6+027 and km 6+052, the stream power attained a value high enough about (ω=159.6 $N \cdot m^{-1} s^{-1}$) to trigger bedload transport to parts of the cross-section where water depth on average was higher than the critical one, i.e. h_{cr} = 0.39 m. In consequence, the stream power in this cross-section decreased to ω= 130.35 $N \cdot m^{-1} s^{-1}$, thus reducing sediment transport capacity and causing gradual deposition of bed material and reconstruction of existing sandbars. Under flow regime where stream power increased to ω= 257.6 $N \cdot m^{-1} s^{-1}$, a migration of the bars was observed. The transport of bedload, calculated for these conditions (g_s = 276.2 $N \cdot m^{-1} s^{-1}$ in cross-section km 6+120 and in cross-section km 6+027 g_s = 239.4 $N \cdot m^{-1} s^{-1}$) indicated that the budget of sediment inflowing and outflowing was not preserved. Instability of water and sediment transport triggered morphological changes in the stream channel, causing widening of the section by lateral erosion. On a degraded sector of the stream channel spatial distribution of the stream power showed that even for a discharge approximate to the bankfull discharge (Q_b=27.7 $m^3 \cdot s^{-1}$), local stream power is too small (ω=0.73 $N \cdot m^{-1} s^{-1}$) to trigger bedload transport.

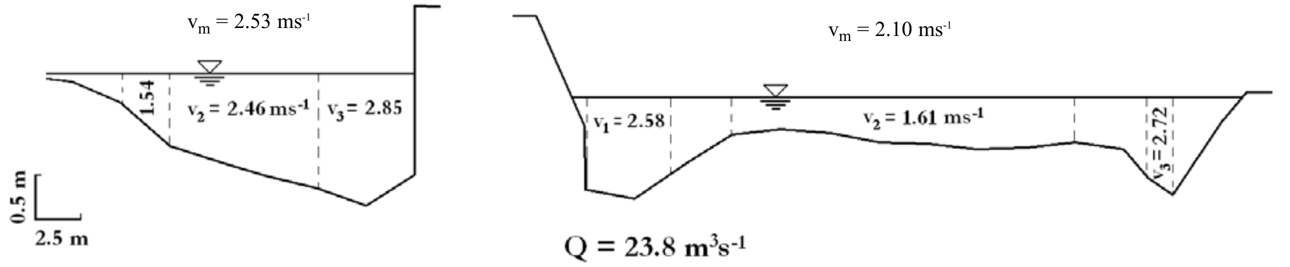

Fig. 6. Water flow velocity along cross-section for discharge Q= 23.8 $m^3 \cdot s^{-1}$, Mszanka Stream. The broken lines define subsections of the cross-section division for which local velocities, shear stresses and stream power were calculated.

Table 2. Parameters of hydraulic conditions along the research reach of Mszanka Stream for a freshet event with a discharge of 23.8 $m^3 \cdot s^{-1}$.

C-S [m]	Flow velocity v [ms^{-1}]				Shear stress τ [$N \cdot m^{-2}$]				Stream power w [$N \cdot m^{-1} \cdot s^{-1}$]			
	v_m	v_1	v_2	v_3	τ_m	τ_1	τ_2	τ_3	ω_m	ω_1	ω_2	ω_3
6,220	2.53	1.54	2.46	2.85	47.00	22.49	46.94	58.07	118.91	34.63	115.47	165.5
6,120	2.10	2.58	1.61	2.72	41.51	51.84	26.03	58.70	87.17	133.75	41.91	159.6
6,095	2.00	2.65	1.27	1.89	35.11	49.19	17.07	34.18	70.22	130.35	21.68	64.60
6,052	1.85	2.80	1.66	0.32	120.9	49.97	23.69	2.27	223.67	139.92	39.33	0.73
6,027	2.63	1.92	2.30	3.42	54.93	33.28	42.92	75.33	144.47	63.90	98.72	257.6

Table 3. Absolute and relative errors for the mean values of hydraulic conditions for discharge 23.8 $m^3 \cdot s^{-1}$, Mszanka Stream, 2006.

Cross-section	Error of flow velocity v_m		Error of shear stress τ_m		Error of stream power ω_m	
	Relative [%]	Absolute [m/s]	Relative [%]	Absolute [N/m^2]	Relative [%]	Absolute [N/m/s]
6,220	0.003	0.008	0.003	0.14	0.006	0.71
6,120	0.003	0.006	0.004	0.17	0.007	0.61
6,095	0.003	0.006	0.003	0.11	0.006	0.42
6,052	0.004	0.007	0.002	0.24	0.006	1.34
6,027	0.003	0.008	0.002	0.11	0.005	0.72

Table 4. Parameters of hydraulic conditions along the research reach of Targaniczanka Stream, 2006 for $Q_{50\%}$ and bankfull Q_b discharges.

Cross-section [km]	Q [$m^3 \cdot s^{-1}$]	Flow velocity v [$m \cdot s^{-1}$]			Shear stress τ [$N \cdot m^{-2}$]			Stream power ω [$N \cdot m^{-1} \cdot s^{-1}$]			g'_s [$N \cdot m^{-1} \cdot s^{-1}$]
		mean			mean			mean			
		1	2	3	1	2	3	1	2	3	
2+736	$Q_{50\%}$ = 7.90	1.48			30.48			45.11			48.23
		1.96	0.53	1.86	46.47	6.02	33.42	91.08	3.19	62.16	
2+609		1.59			32.63			51.88			52.61
		1.83	0.79	1.91	39.93	10.25	38.99	73.07	8.10	74.47	
2+547		1.42			23.40			33.23			14.30
		0.84	1.41	1.59	10.52	23.23	27.63	8.84	32.75	43.93	
2+736	Q_b = 82.80	3.19			83.30			265.73			227.23
		3.45	2.93	3.81	94.52	74.51	106.69	326.09	218.31	406.49	
2+609		2.54			45.18			114.76			221.75
		2.52	2.28	2.69	43.30	36.82	48.70	109.12	83.95	131.00	
2+547		2.44			38.35			93.57			188.02
		2.22	2.30	2.38	32.50	33.61	35.78	72.15	77.30	85.16	

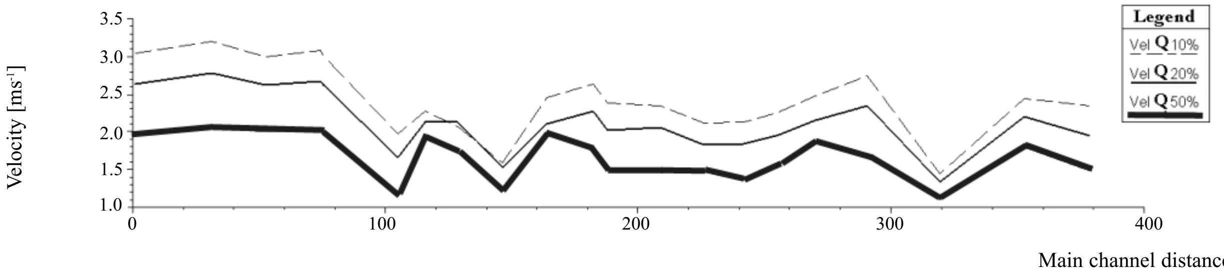

Fig. 7. Total water flow velocity v_m along the research reach for discharge $Q_{50\%}$, $Q_{20\%}$, and $Q_{10\%}$, Targaniczanka Stream, 2004.

Table 3 presents relative and absolute errors calculated for the mean values of hydraulic parameters; flow velocity v_m, shear stress τ_m and stream power ω_m. The method of logarithmic derivative was used. Absolute errors of water depth (Δh=0.03m), slope of energy line error ($\Delta J=1\cdot10^{-6}$), and cross-section area ($\Delta F=0.01\ m^2$) were determined by HEC-RAS. Calculation errors for local parameters (Table 2) are of the same order.

Analogous calculations and analysis of measurement results were performed for a sector of Targaniczanka Stream. The results are given in Table 4.

The various configurations of stream channel Targaniczanka on the examined sector has resulted in various hydraulic conditions in its cross-section. For a mean flow $Q_{50\%} = 7.90\ m^3\cdot s^{-1}$ in cross-section km 2+736, the mean velocity was $v = 1.48\ m\cdot s^{-1}$. A detailed analysis of velocity in particular regions of the section shows that the velocity changes from $v = 0.53\ m\cdot s^{-1}$ (bar) to $v=1.96\ m\cdot s^{-1}$ (ripple). In consequence, shear stress was estimated within the range $\tau = 6.02 – 46.47\ N\cdot m^{-2}$ (mean value $30.48\ N\cdot m^{-2}$). In the case of bank discharge ($Q_b = 82.8\ m^3\cdot s^{-1}$) in the cross-section km 2+736 in the year 2004, velocities adopted values from $v = 2.93\ m\cdot s^{-1}$ to $v = 3.81\ m\cdot s^{-1}$, resulting in shear stresses from $\tau = 74.51\ N\cdot m^{-2}$ to $\tau = 106.69\ N\cdot m^{-2}$ and causing changes in the bedload transport.

Spatial changes in velocity vm are illustrated in Fig. 7. The visible changes of values of velocity are calculated using the width of the cross section and its morphology as well as bed slope. For a flow $Q_{10\%}$, the initial velocity on the studied sector (cross-section km 2+837) decreased from $v_m = 2.2$ to $1.3\ m\cdot s^{-1}$. This is connected with the widening of the channel from b = 14.2 m to b = 23.5 m, the occurrence of chutes-pools and initiation of middle bar formation. Similar changes can be identified in consequent sections – a consequent ripple occurs in cross-section km 2+609, at the same time the influence of the bridge which effects in changes of water flow regime can be observed.

Hydrodynamic condition changes along the studied reach triggered morphological changes of the channel. For instance, in 2004 for discharge Q_b, average velocities were estimated to range from $v = 1.39$ to $3.90\ m\cdot s^{-1}$, and shear stresses from $\tau = 11.53$ to $94.47\ N\cdot m^{-2}$. The flood events which took place in August 2005 of a discharge approximate to $Q_{1\%}$ changed the riverbed configuration on the studied reach. For the newly formed bottom system, shear stresses for discharge Q_b ranges in the studied sector from $\tau = 32.50\ N\cdot m^{-2}$ to $\tau= 106.69\ N\cdot m^{-2}$. In the year 2004 (before the major flood of 2005), highest values of flow parameters occurred in cross-section km 2+736 on the left side of the channel, whereas in 2006 the highest values were observed on the right side undergoing changes alternately from cross-section to cross-section. Moreover, water surface elevation decreased by 0.1 m in 2006.

Conclusions

The analysis shows that dynamics of flows causes deposition of sediments on the river bed, but only its partial migration. The variability of characteristics such as channel width, flow depth, water flow velocity and hydraulic gradient showed that the higher the degree of river bed degradation, the smaller the flow needed to cause further degradation.

The degraded sectors are characterized by changeability of cross-sections and local changes of bed slope that both lead to creation of instable bed forms. Stream power was not uniformly distributed in cross-sections, resulting in sediment transport occurring only locally. A comparison of the inflowing and outflowing quantity of sediments on the studied sections showed that the deposition process prevails. It also is in some connection with the processes of lateral erosion caused by excessive power of the stream that enlarges the channel by undercutting its banks. This provided additional supply of sediments into the stream, depending on water flow quantity and shearing stresses in the channel. The geometry of the sections, however, does not guarantee sediment transport through whole sections. In places where the stream power is too low, accumulation of sediment takes place.

In the investigation period on both stream sectors, the main current was winding and the chutes and pools occurred, and this may evidence a tendency to stabilization of their channels.

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