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CHANGES OF THE MORPHOLOGY OF THE ROPA RIVER — UPSTREAM AND DOWNSTREAM OF THE KLIMKÓWKA WATER RESERVOIR

Abstract: The paper outlines changes in the channel morphology of the Ropa riverbed over the last six years, taking into account the role of large floods and the Klimkówka water reservoir in shaping the morphology of the riverbed. The analysis was based on annual geodetic measurements of the Ropa riverbed conducted between 2009–2014. The research was carried out in four cross profiles of the riverbed located upstream (1 profile) and downstream (3 profiles) of the reservoir. In order to recognise the direction and scale of morphology changes of the riverbed, additional analyses of water levels in the Ropa River was performed in the analysed multiannual period. The conducted analysis led to the conclusion that floods with extremely large discharges are the key factor causing the deepening of the riverbed downstream from the reservoir. It can be up to about 70 cm deep during a single event. The reservoir is just one additional factor of many which shape the direction and scale of changes to the riverbed. A significant role in modifying the riverbed morphology upstream from the reservoir is played by river control works, which diminish the effects of sediment accumulation occurring on this section.

Key words: channel morphology, riverbed, floods, Klimkówka water reservoir, Ropa River, Carpathians

INTRODUCTION

One of the most noticeable geomorphological river processes is river channel deepening. In the Polish Carpathians, the deepening in recent decades recorded significant values ranging from 0.5 m to 4 m (Wyżga 2008). The main reason behind rapid river channel deepening are both natural and anthropogenic factors. K. Krzemień (2006) claims that in areas with high anthropogenic pressure, rivers and streams adjust the structure of channel systems to the changing environmental conditions in valley beds and slopes. Morphology changes of channels are a result of channel regulation and river material extracting, and additionally, to a lesser extent, the different land use structures in water basin areas (Korpak et al. 2008). L. Dauksza (2009) states that the rate with which the Ropa River deepens depends on lithology, landslides on the river channel banks and hydrotechnical constructions. Regardless of other factors, large floods have an impact on channel morphology, in particular those which take the clustering form, i.e. when few flood events come one after another within a short period of time (e.g. Starkel 2003; Korpak et al. 2008; Wiejaczka, Bochenek 2013). Large floods play a special role in shaping the morphology of dammed river channels because such hydrotechnical constructions divide the river channel into two sections which, develop in different ways (Korpak 2008). Upstream of dams, the accumulation of sediment transported by water is the dominant process, while downstream, it is the erosion of the bed of the channel. One of the basic and immediate geomorphological effects of dam developments is the degradation of riverbeds (e.g. Brandt 2000; Petts, Gurnell 2005).

In the Polish Carpathians there are over a dozen dam reservoirs located on the majority of main rivers. They are between about 20–80 years old. The development of the hydrological construction sector in the Polish Carpathians was mainly due to the need to balance the uneven water supply of rivers throughout the year (Wiejaczka 2010). The morphology changes of Carpathian river channels due to dam and reservoir constructions are not described in much detail. The several papers which do refer to this problem do not exhaust this complex issue which remains difficult to document (e.g. Łajczak 1995; Malarz 2004–2005; Książek 2006; Wiejaczka 2011; Wiejaczka, Kijowska 2011; Wiejaczka, Bochenek 2013; Liro 2014a, b).

L. Daukasza (2009) show that there are two approaches to monitor channel changes. The first is morphological mapping of the channel formation on the basis of available topographic maps. This method gives only qualitative data to evaluate channel changes, especially lateral erosion, and, to a lesser extent also vertical erosion. The second surveying method coupled with the first approach gives both qualitative and quantitative data. Analysis of morphology channel changes can also be performed based on minimal water level measurements over a longer period of time (Wiejaczka, Kijowska 2011).

The objective of the current paper is to document changes and recognise factors which influence the morphology of the Ropa River channel bed — both upstream and downstream of the Klimkówka water reservoir over the period of the last six years. Based on field research and archival data an attempt was made to assess the role of the reservoir in shaping the channel morphology of the river.

LOCATION AND METHODOLOGY

The research was conducted within the Beskid Niski area which is the lowest in the arc of the Polish Carpathians. The Ropa River is the biggest left tributary of the Wisłoka River (basin a of the upper Vistula River) which provides drainage for the western part of the Beskid Niski Mts. The total length of the river amounts to 80 km, its gradient equals 5.89% and the water basin area amounts to 974 km^2. The analysed section of the Ropa River between Uście Gorlickie and Szymbark (Fig. 1) is located within the Magura Unit. The Ropa River basin area is made up of weathering-resistant, inoceramous formations from the Tertiary period (sandstone and shale), Magura shale, sandstone and marls which make up the highest mountain ridges. River valleys were carved in less resistant shale and sub-Magura, hieroglyph sandstone, conglomerates and coloured shale.

The Ropa river valley in the analysed section is a flat-bottomed valley. In a few places it takes on the form of a river gorge. The Ropa River channel is carved out in the gravelly terrace which forms the valley floor. The width of the channel in the upper course (upstream from the Klimkówka water reservoir) ranges between 10–14 m and 30–40 m at Szymbark. The depth of the channel ranges from 1–1.2 m in the upper part of the valley to 3–3.5 m at Szymbark. The gradients of longitudinal profile changes from 13.5 ‰ at Wysowa to 3.6 ‰ at the villages of Ropa and Szymbark. A larger contrast in gradients occur particularly between river gaps and widenings of the valley floor (D a u k s z a 2009).

A yearly distribution of discharge in the Ropa River indicates a period of high flows in March and April during the spring snowmelt, as well as in June and July caused by intensive precipitation (average annual sum — 829 mm). Low discharge periods come in the autumn and winter months (Fig. 2). Mean annual discharge on the Ropa River below the Klimkówka water reservoir is 2.81 $m^3 \cdot s^{-1}$ (W i e j a c z k a 2011).

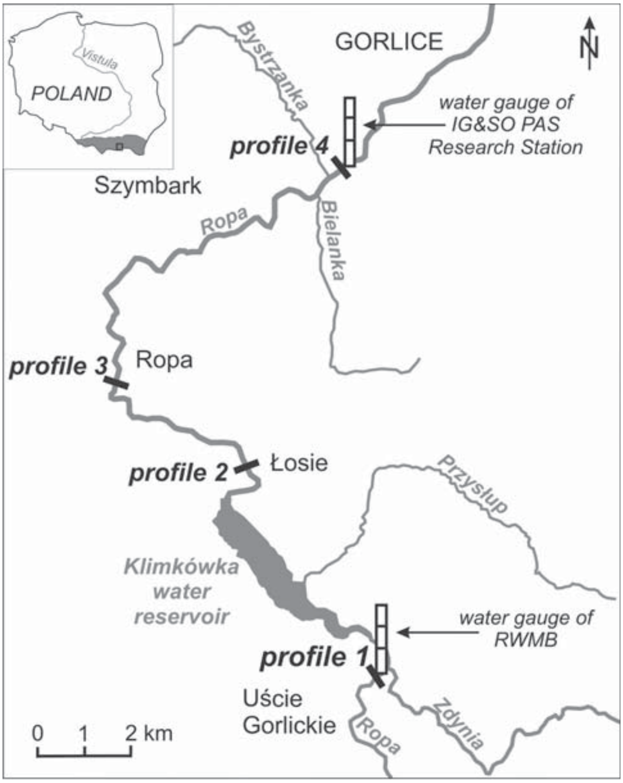

Fig. 1. Study area (location of cross profiles on the Ropa River)

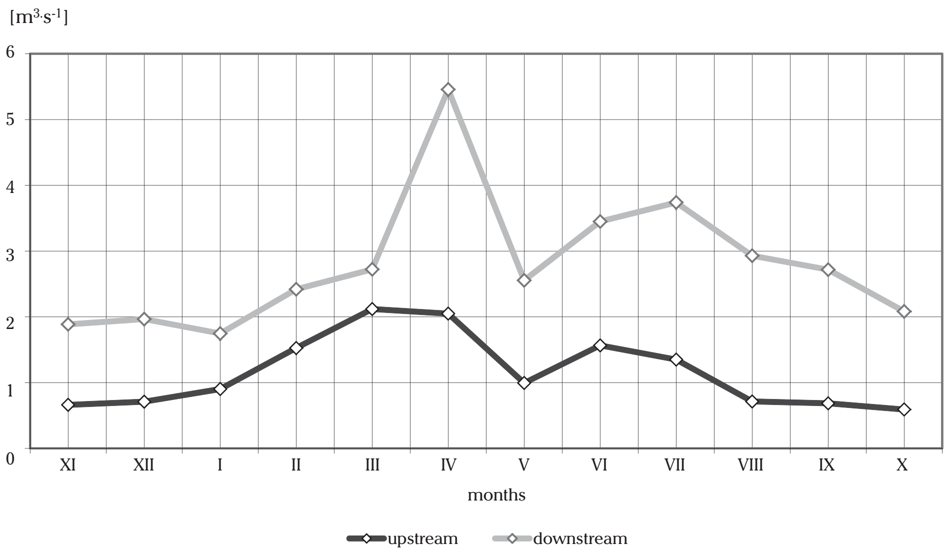

Fig. 2. Mean monthly the Ropa River discharge upstream (excluding the Zdynia River) and downstream of the Klimkówka water reservoir in the years 1995–2006 (after: Wiejaczka 2011)

Analysis of the Ropa channel bed position changes was based on annual surveying (levelling) measurements conducted between 2009–2014. The measurements were conducted in four control cross profiles — one profile was approx. 1.5 km upstream from the Klimkówka water reservoir (Uście Gorlickie) and three were downstream of the reservoir (Łosie — 2 km, Ropa — 6 km and Szymbark — 16 km; Fig. 1, 3). The measurements were taken between autumn and winter, during low-discharge periods. Analysis of data collected during the field measurements was complemented by an analysis of the daily water levels in the Ropa river between 2009–2014 for the water gauges of the Regional Water Management Board (RWMB) and the Research Station in Szymbark belonging to the Institute of Geography and Spatial Organization of the Polish Academy of Sciences (IG&SO PAS).

AN OVERVIEW OF EXISTING RESEARCH ON THE ROPA RIVER CHANNEL MORPHOLOGY

The Ropa River channel morphology research has a long tradition and was documented in several papers throughout the 20th century. An overview of research on the Ropa River channel morphology in the last several decades was outlined in a paper by L. Dauksza (2009). The author claims that from 1969 until 2000 repeated geodetic surveys of the Ropa channel were performed in Szymbark on a 2.5 km long section, after floods which shaped the river channel. Based on those measurements, the map of the Ropa channel was drawn on the scale of 1:500. Given this surveying frequency and accuracy, as well as monitoring of displacement of painted gravels and taken photographs (including terrestrial photogrammetry), it was possible to detect even small changes in the river channel morphology. Results of these investigations up until 1980, in a cross-sectional aspect, were presented in several publications (Dauksza, Gil 1972; Dauksza 1976; Soja 1977; Dauksza et al. 1982). Complementary to the above papers, an analysis of the Ropa channel morphology changes over the last 100 years was presented by L. Dauksza (2009). Based on the analysis of field measurements repeated in 1908, 1969, 1987 and 2000, the author concludes that there is a large temporal changeability of the Ropa River's deepening process ranging from 0 to 120 cm in the given period.

Based on hydrological data analysis, R. Soja (1977) estimated that between 1916–1945 the average rate of the Ropa River channel deepening amounted to 0.4 cm/year and after 1945 — 4.8 cm/year, mainly due to the fact that agriculture activity reduced in the Ropa catchment. In the period 1968–1974, due to several large floods, deepening amounted to 8.2 cm/year. Surveying measurements in two cross profiles of the Ropa channel located in Szymbark for the years 1969–1974 confirm this observed tendency for the riverbed to deepen, as well as the scale of the process. The author explains that the rapid deepening of the Ropa channel is due to the overlap of natural deepening processes with two additional factors. Firstly, an anthropogenic factor, i.e. land use structure in the Ropa catchment area, the intake of gravel from the riverbed and channel regulation. Secondly, a climatic factor is also play an important role, i.e. high and frequent floods caused by continuous rainfalls amounting to 300 mm. The author observes that the size of the flood does not always translate into size of the channel erosion. For instance, after the July 1970 flood (maximum flow: 267 $m^3 \cdot s^{-1}$), the Ropa channel deepened by 50 cm at most

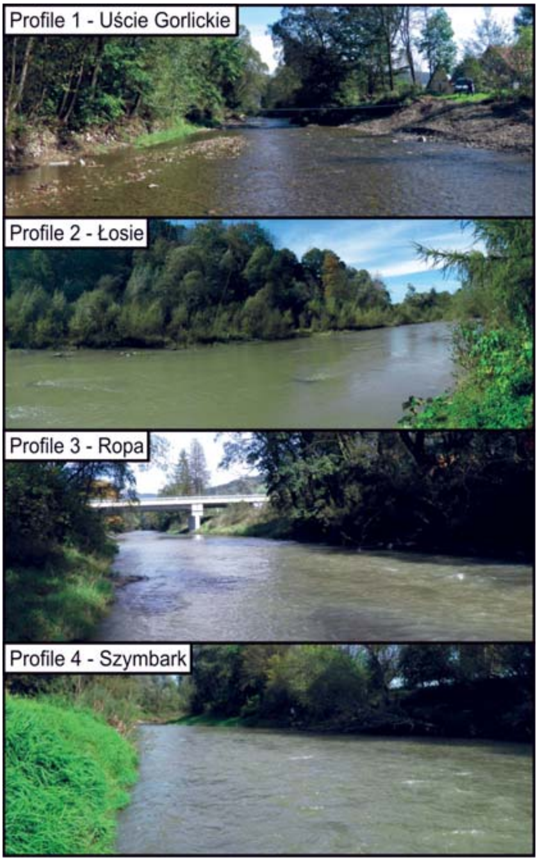

Fig. 3. The Ropa River at the sections where cross profiles of the channel bed are located

while during a much larger flood in July 1973, the deepening amounted to only half that value.

The analysis of minimum water levels in the Ropa River between 1995 and 2010 was based on readings from a water gauge which is a part of hydrological forecasting and warning system of the Klimkówka water reservoir and is located approx. 1 km upstream from the reservoir. In the paper, Ł. Wiejaczka and M. Kijowska (2011) indicate that there are periodical fluctuations in the position of the bed of the Ropa River channel in its upper course resulting from natural and anthropogenic reasons. The natural raising of the the Ropa riverbed channel was related to the increased process of sediment accumulation during floods. The raised bed of the Ropa channel was also a result of channel regulation conducted on the analysed segment of the river. In the analysed period, for the given water gauge, the process of raising the bed of the Ropa channel was a dominant one with an average rate estimated to amount to 3.5 cm/year.

In 2009, monitoring of the bed of the Ropa channel was commenced at the IG&SO PAS Research Station in Szymbark. It was performed in the chosen cross profiles located within different distances from the Klimkówka water reservoir developed in 1994. Initial findings from levelling measurements at the control profiles were presented in a publication by Ł. Wiejaczka and W. Bochenek (2013). The authors analysed the role of floods with extreme discharge for the Ropa River from May and June 2010 in shaping the morphology of the channel bed. The authors concluded, among others, that erosion of the bed of the Ropa channel is the dominant process downstream of the Klimkówka water reservoir during floods. This is due to the fact that a large volume of water flowing out of the reservoir does not carry material and thus it uses its energy on erosion of the channel. As a result of the floods, there was a significant lowering of the Ropa River channel bed, in particular in the segments with an alluvial bed. The scale of the erosion of the riverbed was less pronounced, the further from the reservoir it was. This suggests a weakening impact of the reservoir on the channel processes further down the course of the river.

RESULTS OF FIELD MEASUREMENTS FOR THE PERIOD 2009–2014

PROFILE OF THE BED OF THE ROPA CHANNEL IN UŚCIE GORLICKIE

According to Ł. Wiejaczka and W. Bochenek (2013), the bed of the river channel in profile 1 in Uście Gorlickie (Fig. 4) in 2009 was 10 m wide. The depth of the channel (in relation to the mark on the river bank) fluctuated between 170 and 198 cm; 190 cm on average. The bed of the channel with a balanced profile was lined with pebbles up to approx. dozen centimeters in diameter. The right bank was slightly sloped in the lower part and steeply sloped in the upper part. The left bank was lined with riprap and had a vertical profile. In 2010, the levelling of the channel was performed indicatively in the same cross-profile as in 2009 because the markers on the banks of the channel were destroyed during the flood in June 2010 (maximum discharge on the Ropa River above the Klimkówka water reservoir and the Zdynia River was 107 $m^3 \cdot s^{-1}$ and 284 $m^3 \cdot s^{-1}$ below the reservoir). As a result of the flood, the river channel became twice as wide when compared to the year before. As a result of intensive lateral erosion (probably occurred during the rising discharge), the left bank moved by 8 to 11 m — at the top and bottom, respectively. A newly formed profile of the right bank was determined as a vertical one with an undercut in its lower section. Shortly after the flood, the profile of the bed of the Ropa channel in the analysed section of the river was unlevelled as a result of the deposition of large volumes of sediment in the form of channel bars. The accumulation took place when the Ropa river water flow slowdown due to the backwater of the reservoir and the higher discharge on the Zdynia River — lateral tributary with the total catchment area 105 km^2. (maximum discharge of the Zdynia River during the flood could be about 50% higher than on the Ropa River with catchment area 71 km^2). In order to maintain the permeability of the channel, its bed was subjected to river control works which levelled the bars (the material was moved towards the right bank) and the bed. The conducted control works and the fact that the marks were destroyed made it impossible to precisely state, based on the levelling measurement, how the position of the bed of the Ropa channel changed in the analysed profile compared to the previous year. The depth of the channel bed in relation to the newly established mark on the left bank included in the range of 153–210 cm (194 cm on average). Analysis of water levels in the water gauge, located approx. 150 m below the described cross-profile of the riverbed, shows that the bed of the channel was raised by up to 20 cm (Wiejaczka, Kijowska 2011).

A year later (2011), build-up on the left bank of the channel was observed. The build-up was due to the fact that local people were dumping organic waste there such as cut branches, mowed grass, etc. In the middle section of the channel, a small deposit of gravel material was observed (up to 5 cm) while in the right part of the channel there was a significant deepening of the bed (up to 0.5 m) and a build-up of the bank with material of anthropogenic origin, i.e. rubble. In 2012, the condition of the bed of the Ropa channel as compared to 2011 underwent changes. The material deposited in the left part of the channel was taken away while the deepening of the bed in the right part was filled in with river and bank material. The topography of the bed of the channel became similar to that in 2010. In the right bank no major changes were observed. In 2013 a more significant transformation of the bed of the Ropa channel took place. In the left part, at a length of 8 m, the channel deepened by 20–60 cm. On the other hand, on the right side of the channel, a bar was created approx. 9 m wide and on average 35 cm above the channel bed from 2012.

In 2014 the bed of the channel was levelled throughout its width by river control works in the channel. Instead of a bar, the bed was deepened by up to 80 cm compared to the previous year. That year saw the largest incision and the lowest position of the Ropa riverbed in the entire analysed period. The tendency towards raising of the riverbed throughout the years 2010–2014 in the analysed cross-section reflects the bed position in this period (Tab. 1). Changes observed in the Ropa channel at the point where the profile was located in 2011–2014 were mainly due to human activity rather than natural shaping of the channel during floods.

PROFILE OF THE BED OF THE ROPA CHANNEL IN ŁOSIE

The trend in the position of the Ropa channel bed at the cross profile 2 in Łosie (Fig. 4) over the years 2009–2014 is presented in table 1. The width of the bed of the Ropa channel amounted to 26 m in 2009 and the depth in relation to the mark ranged between 47 and 100 cm (74 cm on average). The bed of the channel was unlevelled and lined with loose material, mainly with boulders of varying sizes which came from the erosion of the bed and banks of the Ropa River channel. Levelling measurements conducted in 2010 showed a significant deepening of the Ropa channel ranging from about 2–69 cm (35 cm on average). It needs to be noted that the greatest erosion of the bed happened near the right bank; this means that the former slope of the bed towards the right bank was maintained. Such significant erosion has not been observed in the remaining control profiles (Wiejaczka, Bochenek, 2013). Such a significant extent of bed erosion was undoubtedly due to the small distance between the profile and the dam, as well as the high energy of the water without sediment that was discharged from the reservoir during the floods in 2010.

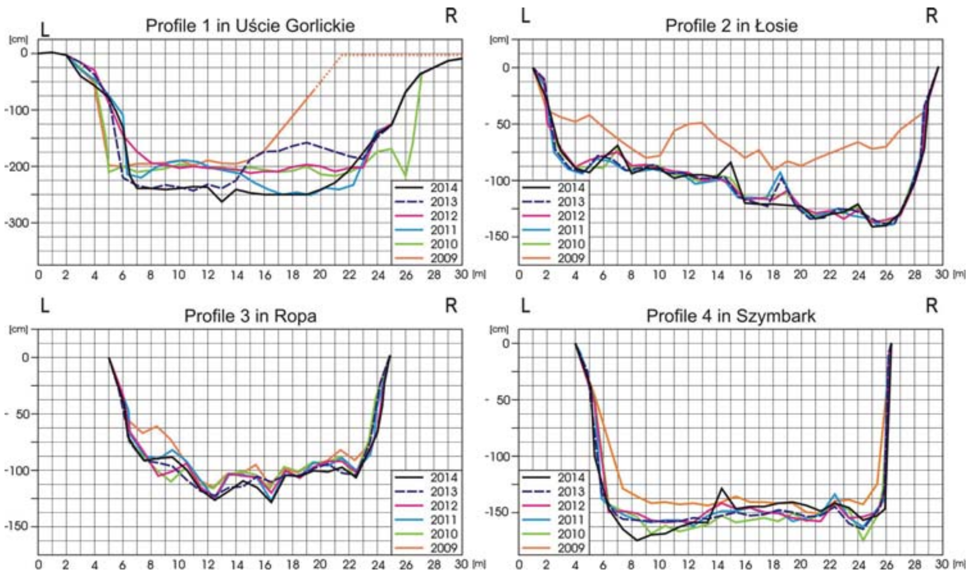

Fig. 4. Cross morphological profiles of the Ropa riverbed in the years 2009–2014

Between 2011–2013 the bed of the Ropa channel did not change significantly because the lack of floods with a high erosive force made it impossible for the river to make an incision in the bed of the channel. Neither was there a process of accumulation that was present in the remaining profiles. After floods in 2014 there was no significant morphological changes within the bed of the channel.

PROFILE OF THE BED OF THE ROPA CHANNEL IN ROPA

The trends of bed position changes in the Ropa River at the analysed cross profile 3 in the Ropa village are presented in table 1. The Ropa river channel in the profile (Fig. 4) was 17 metres wide both in 2009 and 2010. The bed of the channel in that point is not level with numerous depressions carved into the rock outcrops (shale). In 2009 the depth of the bed of the channel, in relation to the mark, ranged between 56 and 115 cm (90 cm on average). After the floods of 2010, the depth of the channel bed ranged between 73 and 116 cm (Wiejaczka, Bochenek 2013). It should be note that only small gravel bars located at the edge of the channel underwent some changes and the central part of the profile with the rock outcrop remained unchanged. From 2011, levelling measurements showed a tendency for alternate forming and subsequent removal of the bar from the left bank of the channel and regular erosion of the bed (1–10 cm) in the middle and right side of the cross-section. The floods from 2014 caused intensified erosion of the bed which made an incision in the Ropa channel that was

Table 1

Position of the Ropa River channel bed in the cross profiles (in reference to the marks on the banks)

channel bed position [cm]	profile 1 in Uście Gorlickie					
	2009	2010	2011	2012	2013	2014
maximum	–	210	248	209	240	229
minimum	–	153	186	194	155	215
average	–	194	218	201	201	222
profile 2 in Łosie						
maximum	100	143	139	138	137	142
minimum	47	53	74	49	72	69
average	74	109	105	104	105	105
profile 3 in Ropa						
maximum	115	116	127	122	122	128
minimum	56	73	68	74	74	66
average	90	98	97	102	102	100
profile 4 in Szymbark						
maximum	152	175	163	159	165	185
minimum	125	143	134	133	129	139
average	140	156	151	151	152	162

the deepest in the entire 6 year period of observation (19 cm at the most in relation to 2013). One needs to recognise that the visible differences between the channel bed position in the given years may result partially from a measurement error as it is very difficult to position a level staff in the same place when the bed is very uneven.

PROFILE OF THE BED OF THE ROPA CHANNEL IN SZYMBARK

The changes of morphology within the bed of the Ropa channel at profile 4 located in Szymbark reflects the position of the bed in the years 2009–2014 (Tab. 1). In 2009, the bed of the Ropa channel in the profile (Fig. 4), approx. 16 km downstream from the Klimkówka water reservoir, was 18 m wide and its cross profile when compared to the profiles 2 and 3 in Łosie and Ropa was more aligned. The position of the channel bed in relation to the mark on the bank ranged 125–152 cm and 140 cm on average (62–152 cm and 136 cm on average of the channel depth taking into account right bank eroded in 2010). After the floods in May and June 2010, there was a significant decreasing of the riverbed position in the entire cross profile, ranging from about 1–50 cm and 16 cm on average (20 cm on average with right bank position from 2009). The width of the channel slightly increased by 1 m, but the cross profile of the bed shaped by the floods still had a similar course to the one in 2009. The extent of bed erosion was much smaller compared to the profile 2 located in Łosie which was within a short distance of the dam (Wiejaczka, Bochenek 2013).

In the following years (2011–2013), when no major floods were recorded, there was an weak deposition of bed material on the river (as a result of slow

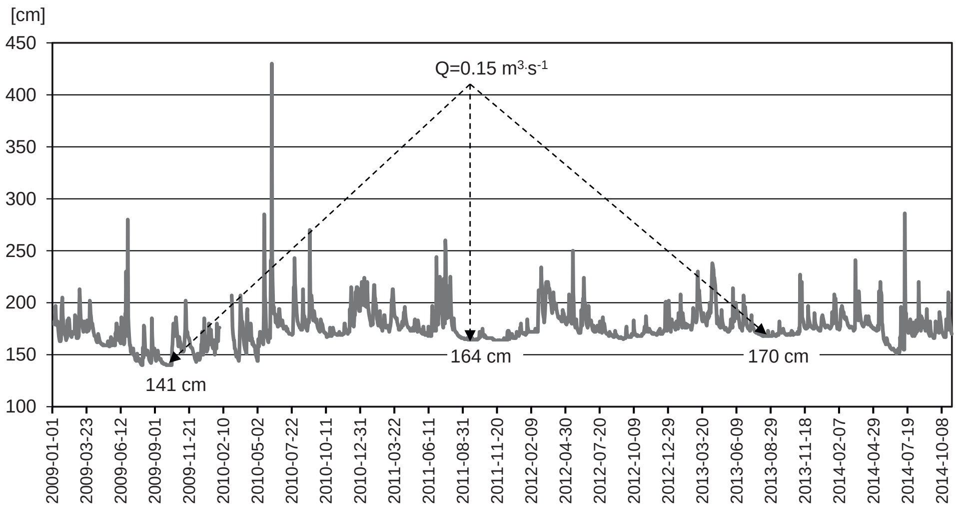

Fig. 5. Daily water levels in the Ropa River between 2009 and 2014 at RWMB water gauge (Kraków) in Uście Gorlickie (with marked water levels for discharge equal to 0.15 $m^3 \cdot s^{-1}$)

transport of the bed substrate within the channel during higher flows) across the width of the profile. This resulted in the Ropa channel becoming more shallow — by 5–10 cm over the course of three years. In 2014, as a result of four summer floods (the largest in May), the channel at the base of the left bank deepened by 6–30 cm compared to 2013. On the other hand, in the middle and right part of the bed cross profile, river material accumulated to a height of 4–12 cm.

WATER LEVEL ANALYSIS

The above results of the Ropa River geodetic channel bed measurements at profile 1, located at Uście Gorlickie (upstream from the reservoir), and at profile 4, in Szymbark (downstream from the reservoir), is confirmed by the water level analysis at the water gauge of the Regional Water Management Board (RWMB) and the IG&SO PAS Research Station which are located approx. 100–150 m below the surveying cross profiles in the years 2009–2014 (Fig. 1, 5, 6, 7, 8).

The analysis of daily water levels in the Ropa River at Uście Gorlickie (Fig. 5) shows that at the flow of 0.15 $m^3 \cdot s^{-1}$ in 2009, the water level oscillated around 141 cm; while in 2011, with the same flow rate, the water level amounted to 164 cm. The raising of the bed by 23 cm was the result of a large flood from June 2010 when intensive accumulation of river material in that section of the river was observed. It could be caused by two factors, i.e. the backwater pinching out further upstream as well as the fact that the Ropa River could be blocked by the Zdynia River (Fig. 1) which has a higher flow than the Ropa River. In 2013 a further build-up of the bed of the channel was observed which is indicated by the fact that the water level is several centimetres higher even though the flow remained the same. The impact of the 2010 flood on the raising of the Ropa river bed is also noticeable in the measurements of the minimum water levels in the river (Fig. 6).

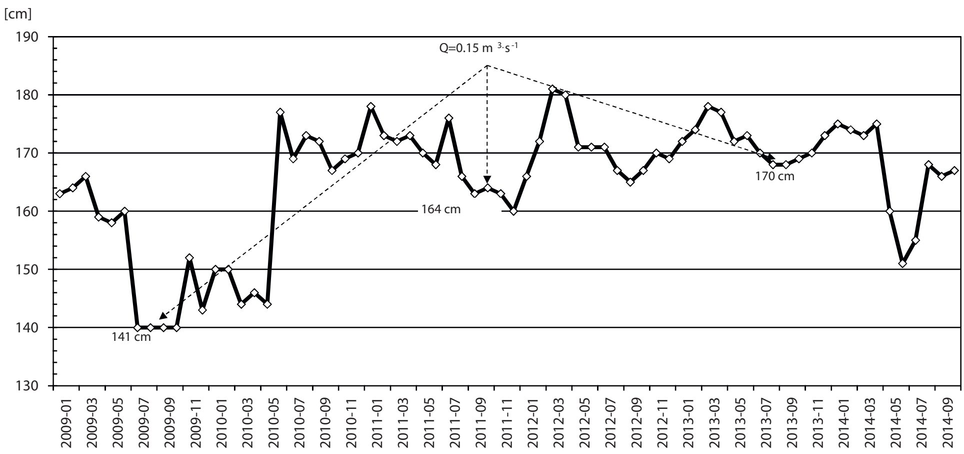

Fig. 6. Minimum monthly water levels at the Ropa River between 2009 and 2014 at RWMB water gauge (Kraków) in Uście Gorlickie (with marked water levels for discharge equal to 0.15 $m^3 \cdot s^{-1}$)

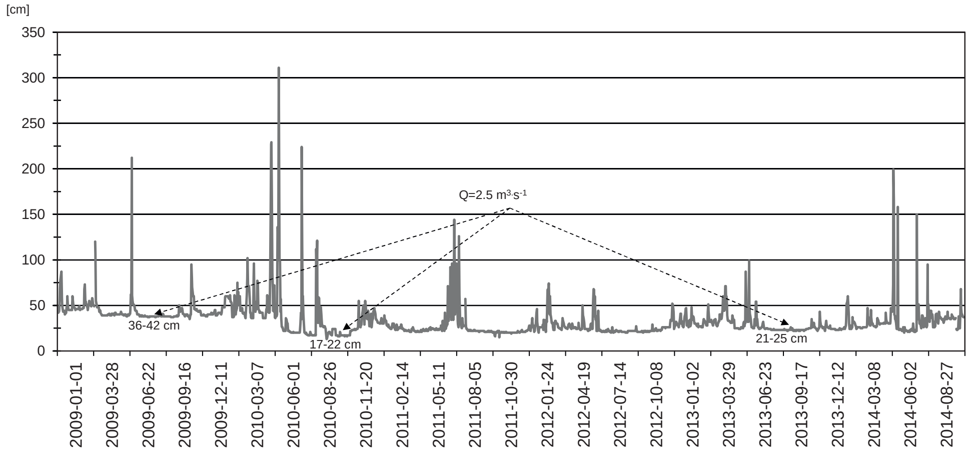

Fig. 7. Daily water levels at the Ropa River between 2009 and 2014 at IG&SO PAS Research Station water gauge in Szymbark (with marked water levels for discharge equal to 2.5 $m^{3}\cdot s^{-1}$)

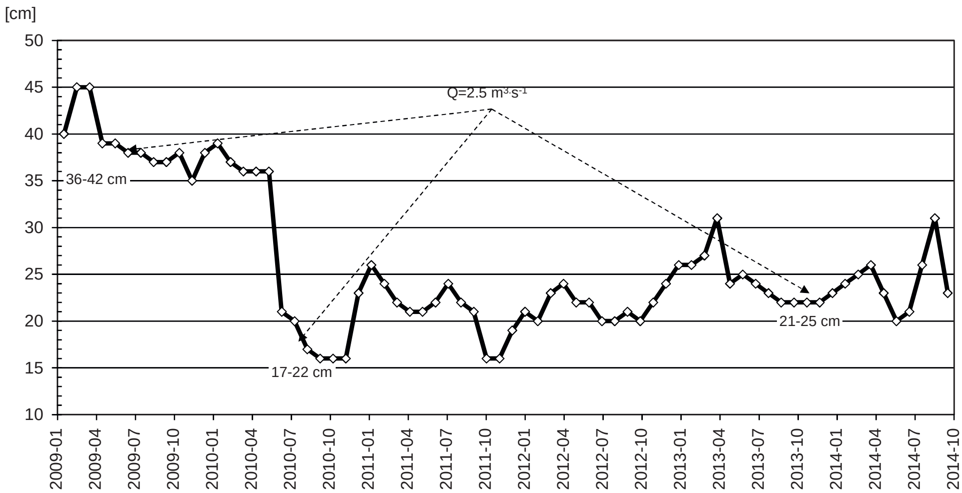

Fig. 8. Minimum monthly water levels at the Ropa River between 2009 and 2014 at IG&SO PAS Research Station water gauge in Szymbark (with marked water levels for discharge equal to 2.5 $m^{3}\cdot s^{-1}$)

The discharge of the Ropa River about 16 kilometres downstream from the Klimkówka water reservoir is to a large extent determined by the volume of water outflowing from the reservoir. According to Ł. Wiejaczka and W. Bochenek (2013), outside the flood period, the discharge is maintained at approx. 2.5 $m^{3}\cdot s^{-1}$. Before the 2010 floods at the above given discharge, the water level ranged from between 36 and 42 cm (Fig. 7, 8). After the flood wave with extreme discharge, the water level with similar hydrologic conditions ranged from between 16 and 22 cm. The average decrease of the bed of the Ropa channel in the water gauge at Szymbark amounted to 19 cm; this value is similar to the above results of geodetic measurements in the cross profile. In the following years the water level at a discharge of approx. 2.5 $m^3 \cdot s^{-1}$ increased and reached between 21–25 cm which confirms the conclusions drawn from the results of geodetic measurements, i.e. that there was a poor accumulation of bed material in the years without extreme floods.

DISCUSSION

The current analysis of morphology dynamics of the bed of the Ropa channel was based on a six-year-long monitoring period of the chosen cross-sections of the river bed located both upstream and downstream from the Klimkówka water reservoir. The analysis forms a basis for outlining the current tendencies in morphology changes of the channel bed of the Ropa River. Floods with extremely high flows are the main factor which shapes the channel morphology of the river.

The dominant morphology process in the profiles located downstream from the reservoir is the deepening of the channel; this can be as much as about 70 cm during large floods. Preliminary determinations suggest that the scale of this process depends on the number and size of floods in a given year, the lithology of the bed and the distance from the reservoir. The greatest changes in the position of the channel bed were recorded within the alluvial bed of the channel and the smallest within the rock outcrops of the channel. This is a common tendency. Moreover, the greater distance from the reservoir, the lower scale of the riverbed incision. This is related to the accumulation of the transported sediment further down and the decrease of the erosive force of the river caused by the reservoir, i.e. the hungry water effect (e.g. Kondolf 1997). In the analysed section of the Ropa channel, no impact of channel regulation on morphology was observed. This phenomenon can, however, be observed on many other Carpathian rivers. Smaller floods cause a deepening, ranging from several to over a dozen centimeters and the redeposition of bed material. In the years with no floods, no significant morphology changes of the bed of the Ropa channel were observed.

Over the recent years, in the river channel upstream from the reservoir, accumulation of material transported by the river was a dominant process resulting from the impact of reservoir backwater and additionally from the blocking off of the water by a side tributary — the Zdynia River. This typical tendency to the accumulation, observable also in other rivers with reservoirs (e.g. Makkaveyev 1972; Książek 2006) has been reversed as a result of the Ropa channel regulation; these included reinforcement and building up of the banks, as well as unblocking the channel through levelling of the profile which resulted in the deepening of the channel. The anthropogenic factors have the greatest impact on shaping the Ropa channel at the section where the above mentioned profile was located.

The observed morphology changes on the bed of the Ropa River channel over the six year observation period are typical for Carpathian rivers in recent decades. Similar morphology changes should be expected in the case of other Carpathian rivers divided by reservoirs. The topic needs further, detailed examination.

CONCLUSIONS

1. The dynamics of morphology changes of the Ropa channel over the last six years were diverse and dependent on three main factors, i.e the number and size of the floods, the operations of the Klimkówka water reservoir and river control works which regulate the course of the bed and banks of the channel.
2. In the river channel downstream from the Klimkówka water reservoir, there is a dominant tendency, observable in the majority of Carpathian rivers, for the water to make an incision in the bed from few to about 70 cm per year. An observed spatial variability in the intensity of the incision process which decreases with the distance from the dam suggests that the reservoir has an impact on the direction of changes in the river channel. However, significant deepening of the channel happens only as a result of large floods. The role of the reservoir is secondary.
3. Upstream from the reservoir, deposition of material within the Ropa channel was observed; this was caused by a side tributary blocking the Ropa River and the backwater of the Klimkówka reservoir. The deposition of material is, however, offset by river control works aimed at regulating and unblocking the channel. Therefore, it was the anthropogenic factor that had the greatest impact on shaping the Ropa channel in the analysed section of the river over the last few years.
4. A clear determination of the role of the Klimkówka water reservoir on shaping the morphology of the Ropa channel is difficult as it is one of several coexisting factors that all have an impact on the channel shaping process.

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