Chapter 15

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The Issue of the Snowmelt Flooding on Post-Glacial Rivers Based on the Example of the Łyna River

1. Introduction

The present post-glacial relief of the area of northern Poland is a consequence of environmental changes a result of existence of the glacial - interglacial rhythm, the climate changes that occurred over hundreds of thousands of years, and especially when the youngest Pleistocene – vistulian glaciation. Maximum reach of the so-called continental glacier of the Poznań phase (about 18 800 years BC), achieve the line of the Vistula River Valley, Dobrzyńskie and Masurian Lake Districts (Blaszkiewicz 1998, Drozdowski, Berglun 1976). The development of the Holocene river network caused outflowless areas to be included in the system of surface runoff, with the inclusion of lake gutters in sections of river valleys (Falkowski 1971, Koutaniemi, Rachocki 1981).

Young glacial rivers developed in the last phase of the Vistula river glaciation and present character of the development of typical river bed of young rivers. They are characterized by a poorly created valley (usually one accumulation terrace level and a level of erosion – accumulation). Most riverbeds have poligenetic course, alternately flowing through the melt troughs, post-gacial gutters and flat valley extension, changing the nature of the ground-breaking of fast flowing into a flat, calm and free movement (Glińska-Lewczuk 2006). For this type of systems belong hydrographic systems of the region of Pobrzeże and East Baltic Lake District. They present an average and strongly developed snow regime, with very aligned flows and low variability of diurnal tides (Dynowska 1994, Nowicka 2009). It is the feature of high rates of water retention capacity of soil and lake in the catchment, and also relatively evenly distributed rainfall of low intensity. Flooding on young glacial rivers usually occurs during midwinter thawing and spring. Their main reason of flood is the rapid melting of snow cover, while still frozen ground, is accompanied by rainfall. But in summer, the rising of water levels in the riverbeds is caused by fouling.

The aim of this study is to characterize snowmelt floods of the Łyna river on the background physiographic and meteorological analysis of the catchment. The Łyna river is regarded as the longest river in the Masurian Lake District. The total length of the river is 289 km, the catchment area of 5,989.84 km^2 (including the Polish borders 208.57 km and 5721.65 km^2). The Łyna flows into the Pregoła River (Fig. 1), which in turn flows into the Vistula Lagoon in Kaliningrad Oblast (Russia).

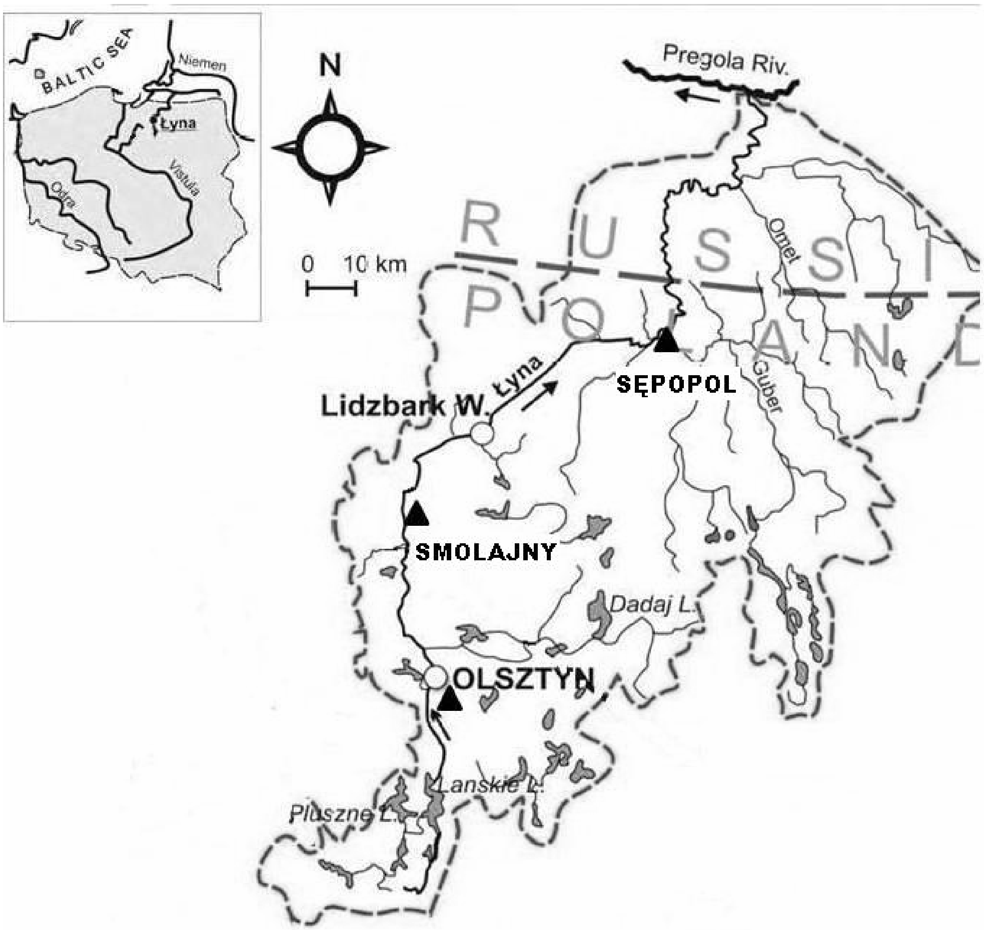

Fig. 1. Location of the Łyna River

A significant impact on the hydrological regime of the Łyna River exerts geomorphological structure of its catchment (Table 1). The oldest geological formations are crystalline rocks (granites) and transformed (gneiss) located about 1000-2000 m below soil surface. On the surface dominated by Quaternary deposits

– Pleistocene glacial origin: moraine clay, sand, gravel and Holocene - settlements in the valleys of river catchments in glacial troughs, depressions in the moraine on rises and washed-out plains. These are: muds, lake marl, peat, alluvial soil, alluvial sands (Klimaszewski 1995). Chains of moraine hills have a course close to the parallel, with a tendency of decreasing towards the north. Their culminations in the southern part of the watershed area reach 217 m a.s.l. Perpendicularly to them there is the valley of Łyna, filling the old gutter. Its feature is the alternating system of breakthrough parts and marginal lake basins, in which, particularly in the southern part, continue to function gutter lakes (among others Łańskie, Pluszne). So diverse surface relief is accompanied by the mosaic of soils. The upper part of the catchment is dominated by podzolic soils, brown, in the central part the medium and light clay (near Olsztyn), and in the lower basin light clay, sand, gravel and clays. Soil variability within the moraine hills aggravate erosion processes. The bottom of the Łyna valley and its tributaries cover hydric soils.

Table 1

Summary of main characteristics of the Łyna catchment

The characteristic of Łyna basin	The Łyna basin		
Surface	5989,84 km^2	In state frontier 5721,6 km^2	Abroad 268, 24 km^2
Length of river	289 km	(In state frontier 208.57 km)	
Length of basin	184 km		
Lakes cover	ok. 1.5%		
	8% in the upper part basin	The bottom of the basin weaker to 0%	
Forest cover	average 26.3%		
	68% in the upper part basin	26.9% in the central part basin	19,48% in the lower part basin
Use of soil	Arable land	41.76%	
	Orchards	0.19%	
	Meadows	8.21%	
	Pastures	2.95%	
	Forests	26.30%	
	Other	20.95%	

The main element of the landscape covering more than half (51%) of the surface of the upper basin are Łyna forests. While in the southern part of the basin, they form large and dense complex located on soils with a significant permeability, whereas in the northern (lower) part of the Łyna catchment are scattered. A characteristic feature of the Łyna catchment is also ,high on the national scale, number of lakes (7% of the area). Therefore, the highest rates of retention capacity should be assigned to the upper basin, and the relatively weaker - the bottom of the basin. A large forest cover and the number of lakes in the upper part basin have a significant impact on the hydrological regime of the river, storing water resulting from melting snow and slowing surface water runoff and snowmelt runoff to the river. Forest cover decreases northward over the Łyna catchment. The use of the Łyna catchment, despite the advantages of agricultural use, in the southern part of the catchment we can observer a bigger amount of forests in comparison to agricultural land, while in the northern more land than forests (Table 1).

2. Results

2.1. Hydrographic system of the basin

The springs of Łyna river are located at an altitude of 153 m a.s.l (Protected as a nature reserve, "Springs of the Łyna River") pass into the valley cut into the 30-40 meters in the surrounding hills. The average slope in the river channel from its sources to Lidzbark Warmiński is 0.69‰, and from Lidzbark Warmiński to the state border amounts to 0.45‰. The Łyna in the upper part flows through several gutter lakes. The largest part Łańskie, Pluszne (on the Łyna River upstream the Marózka river). The largest right bank tributaries include Wadąg, Kirsna, Symsarna, Guber, the left bank: Marózka, Sunia, Elma. The Łyna trough is largely unregulated except for the section of about 10 km above Olsztyn (drained, pump stations), the straightened meandering 6 km section in the village of Smolajny (below Dobre Miasto) and regulation of the trough in the region of Bartoszyce and Lidzbark Warmiński. Among the important structural hydro elements of the river there are five small water power stations. The largest water power station on this river is located on the Russian side in Pravdinsk. Dating from the early twentieth century, the water power station was devastated for many years after the war by the Russians, but again it has been renovated recently. The backwater of the dam lake of this water power station reaches the city of Sępopol.

2.2. Climatic conditions

According to the Polish Climate Atlas (Lorenc 2005) average annual air temperature in the period 1971-2000 of the Łyna catchment area amounts at 7.4°C, and in January -2.4°C, and July 17°C. Average duration of thermal summer is about 80 days. Number of hot days with temperature ≥ 25°C is on average of 25. The number of ground-frost days is 108, and the number of very frosty days with temperatures ≤ -10ºC - 2-3. The number of days with snowfall usually does not exceed 60. Snow here is for an average of 73 days, and its height in the season at an average of 10 cm. Average annual relative humidity is 83%. There are 40 sunny days a year and cloudy around 155. Average annual total rainfall in the Łyna catchment stands at 620 mm (Olsztyn), but for the Olsztyn Lake District is in the range of 600-640 mm, and the Sępoplska Lowland 580-600 mm. During the seasonal distribution of rainfall is observed the superiority of summer half-year over winter half-year. In the period from May to October about 63% of annual total of rainfall occurs. The highest average monthly rainfall (> 70 mm) is observed in June and July. Low rainfalls (<35 mm) are typical for months from January to March, and the minimum monthly rainfall appears in February.

2.3. Analysis of snowmelt floods of post-lake rivers.

Hydrological analysis was based on multi-year data from 1960-2009 from the resources of the Institute of Meteorology and Water Management. For the detailed analysis of flood data from observation for gage station in Olsztyn – Kortowo, Smolajny, Sępopol (Tab. 2), and meteorological for climatological stations in Olsztyn, Kętrzyn and Lidzbark Warmiński. Detailed characteristic of the great flood was developed for the event in March 2005.

Table 2

Summary of gauge stations on the Łyna river

Gauge station	Location [m a.s.l.]	Kilometers [km]	Catchment area [km^2]
Olsztyn - Kortowo	103	218.7	568
Smolajny	71	172. 0	2290
Sępopol	31	89.8	3647

The most classical definition of flooding is the raise of water level in the river caused by increased supply or due to damming of water. Flooding can be divided due to their size into: normal, big or extreme. The base of flood is a matter of convention, usually defined as crossing the flow of Q ≥ Qgr (Ozga-Zielinska, Brzeziński 1994). Depending on the criterion that we adopt (hydrological, economic, biological), it will be varied. The base of flood due to hydrological determinants may be considered (Bajkiewicz-Grabowska, Mikulski 2009):

- an average state of high water of several years SWW (extremely high flood),
- the high state of low water of several years- NWW (high flood),
- state corresponding to the lower limit of high state o several years DGWW (normal flood)

Instead of the water level, discharge can be used to define the level of flooding, which we obtain respectively SWQ, NWQ, GGSQ. Flooding, due to the origin, can be divided into: rain, snowmelt, ice-jam, storm, failures (Dobrowolski 2010).

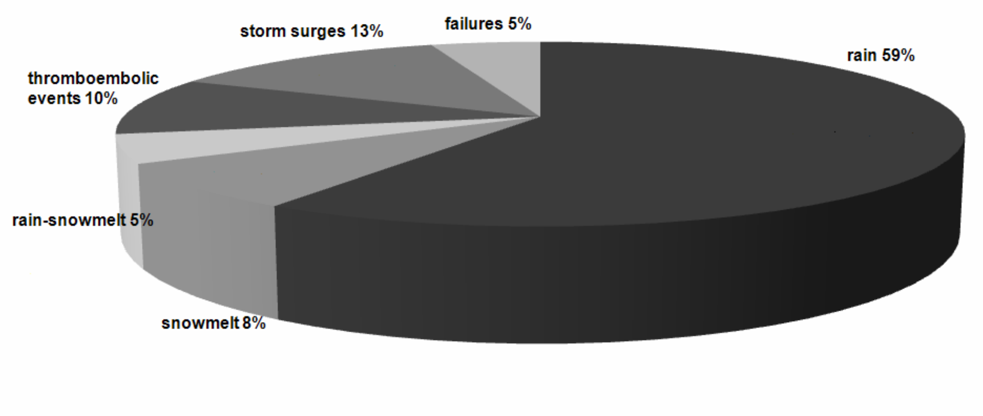

Fig. 2. The number of regional floods in Poland in years 1946-2001 (Dobrowolski *et al.* 2010)

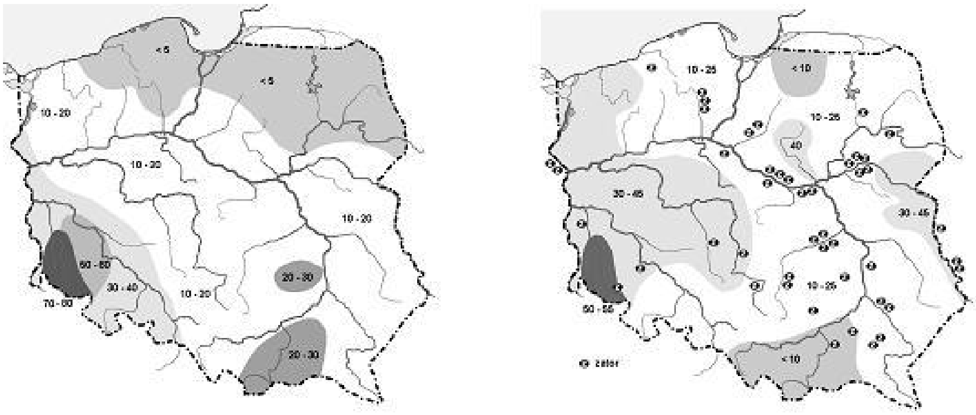

Fig. 3. Polish regions most vulnerable to catastrophic flooding (1946-2001) (Dobrowolski *et al.* 2010)

The Łyna River basin is characterized by areas of low flood risk (Fig. 3).This is confirmed by index Francou or by index K (Bartnik and Jokiel 2010 from Francou and Rodier 1969). It allows you to compare the peak runoff for catchments of different sizes. K index is obtained from the following formula:

$$K = 10 \times \left(1 - \frac{(\log WWQ - 6)}{(\log A - 8)}\right)$$

where:
WWQ – of the multi-year maximum flow [$m^3 * s^{-1}$]
A - the catchment area [km^2]

The indices K calculated for Poland and did not exceed the value of 5.0: Łopuszanka (Sands) – 4.64; House (Łabowa) – 4.26; Miechówka (Miechów) – 4.42 and concerned Carpathian rivers. Lowland rivers are characterized by index K in the range 1-2 (Jokiel, Tomański 2004). The value of K index for the Łyna catchment amounts, depending on the part of the catchment, from K = 0.52 for upper course to K = 1.52 in lower course (Table 3).

The course of extreme weather situations in recent years showed that the young-glacial rivers, despite the weak response to the intense supply, which is expressed by a high hydrological inertia may locally have an intensive supply and disastrous consequences.

2.4. Features of the hydrological regime of the Łyna river

The Łyna River is characterised by a high ratio of catchment retention capacity, resulting from a significant amount of lakes and forest cover and has the features of steady outflow from the basin. The advantage of runoff from melting snow on the total average annual runoff is the type of nival regime. The outflow of the river to the area, should be classified according to Dynowska (1994) as the type of nival medium-created type, as the average spring month runoff is 130-180% of the average annual outflow. At the Smolajny cross section (Fig. 4), the change of the flow fluctuations formed within a year are of 0.6-1.4.

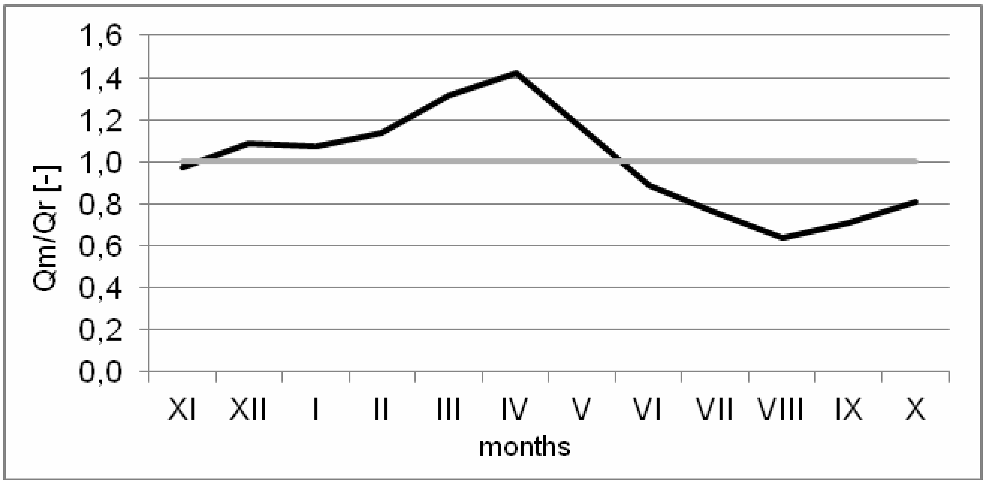

Fig. 4. Changes in monthly flow fluctuations rate at the cross section of Smolajny on the Łyna river

The average runoff from 1 km^2 of the Łyna catchment area is slightly higher than the average for Poland (5.6 dm^{3}s^{-1}km^{-2} by J. Stachy) and stands at 6-8 dm^{3}s^{-1}km^{-2} It shows the tendency to increase towards the north. The share of underground drainage in the general mass of the outflow is 60-75%. In the course of the annual water levels and flow conditions there are selected the one clear and one secondary period, and one clear high water and one distinct low water period (Glińska-Lewczuk 2011). After reaching the spring maximum water levels and flows are markedly reduced. Culminations of levels occur most frequently in spring, in February and March, which is a result of snow melting and thawing. Snowmelt flooding on the Łyna and its tributaries reach climaxes usually higher than the less frequently observed and also shorter rainfall flooding occurring in summer. Due to the high retention capacity of catchment flooding caused by high summer rainfall is low and rising water levels is caused by the overgrowth of the channel.

Hydrological observations and measurements carried out in three sections of Łyna: Olsztyn-Kortowo, Smolajny and Sępopol by the IMGW services in the years 1960-2010 showed that the average annual flow (SSQ) at the cross-sections are respectively: 3.88 m^3s^{-1}; 14.45 m^3s^{-1} and 24.98 m^3s^{-1}, which corresponds to unit outflow from the basin level: 6.83 $l\ s^{-1}\ km^{-2}$, 6.31 $l\ s^{-1}\ km^{-2}$, and 6.84 $l\ s^{-1}\ km^{-2}$. During high water periods, flow rate is 10.7, 50.6 and 172 $l\ s^{-1}\ km^{-2}$.

With the increase in the length of the stream catchment, also increases the amplitude of water levels: from 161 cm to Łyna in Olsztyn, Smolajny by 330 cm, up to 541 cm in Sępopol. Comparison of the maximum level of water table in the river channel and the alarm level is a significant predictor of the behavior the river water. During the observation period of the Łyna at the Olsztyn cross section, alarm conditions (160 cm Olsztyn-Kortowo gauge) was not exceeded (WWW = 159 cm), at Smolajny the maximum alarm level was exceeded by 28 cm, while in Sępopol by 130 cm. The list of states and the characteristic flows of the gauge stations on the Łyna River (Olsztyn – Kortowo, Smolajny, Sępopol) are shown in Table 3.

Table 3

List of characteristic water levels (cm) and discharges ($m^3 * s^{-1}$) for gauge stations at Olsztyn, Smolajny and Sępopol on the Łyna River of multi-year period (1960-2010)

Parameter	**Olsztyn – Kortowo**	**Smolajny**	**Sępopol**
Alarm level	160	300	450
Alert level	140	280	420
WWW	**159** (23.07.1997)	**328** (**407**, 12.01.1916)	**482** (**598**, 31.03.1888)
SWW	130	259	356
GGSS	103	191	211
SSW	85	148	168
DGSS	67	106	127
SNW	50	67	103
NNW	**20** (15.01.1978)	**-2** (15.09.1964)	**59** (**7**, 01.10.1841)
WWQ	**10.7**	**50.6**	**172**
SWQ	6.24	32.64	94.07
GGSQ	4.74	18.7	38.9
SSQ	**3.88**	**14.45**	**24.98**
DGSQ	3.16	10.3	15.85
SNQ	2.3	6.8	9.09
NNQ	**1.36**	**3.76**	**4.6**
Q1%	**11.2**	**64.1**	**221**
K index	*0.52*	*0.74*	*1.52*

2.5. Analysis of the floods on the River Łyna in March 2005

A typical flood characterised by the Łyna, regardless of the cross section at which the observations are conducted, is midwinter or spring snowmelt flooding, while the sudden melting of snow cover from still frozen ground is superimposed by a heavy rainfall. As a result of intense supply, surficial mainly, a strong response of river water takes place in the form of a sudden water rising.

Particularly favourable hydrometeorological conditions for the occurrence of extreme events on the young-glacial rivers of northeastern Poland occurred in spring 2005, i.e. during the period 15-19 March 2005. The analysis of snowmelting on the Łyna flood showed that the main determinant of its height was a high level of groundwater and surface water, high saturation due to heavy rainfall in autumn and winter 2004 (682 mm).

Baric situation, directly proceeding the spring warming in 2005 was characterized by high-pressure centers moving over the area of Poland, which determined low air temperatures and persistence of snow cover. In the middle of the month, the western low-pressure centers brought warm and humid air mass, resulting in an increase in the average daily mean temperature from -1.5ºC to 6.5ºC (about 15 March 2005), accompanied by rainfalls in the amount of 8 mm in the center, up to 20 mm in the eastern part. Intensive melting of snow cover across the basin resulted in the rapid rise of water level in the river and increased flow. The Łyna reached its maximum levels, respectively 3 days (18, 19 March) after the immediate increase in the air temperature. Summary of hydrological and meteorological data for the month of March 2005 for gauge stations Olsztyn – Kortowo, Smolajny and Sępopol are respectively shown in the Tables 4-6.

On 16-17 March 2005, as a result of the rapid increase in the air temperature and rainfall sums in the Łyna catchment area, there was a rapid melting of snow cover (40 cm), which resulted in a significant rise in water level and increase in the flow of the Łyna River. Flood boundary conditions was exceeded for the entire length of Łyna on 18 March 2005. The river reached its maximal levels, respectively in Olsztyn on 18 March, in Smolajny on 19-22 March, in Sępopol on 19 - 21 March. The size of the maximum flows correlated with the water levels. However, the decrease in flows was far slower than the decrease in water levels.

In the cross section of Olsztyn – Kortowo water level dropped below the limit of flooding in two days, while in the cross sections of Sępopol and Smolajny after 10 days. In the course of flooding (Figure 8-10) it was indicated a clear flattening of the rising wave, and its elongation. In Olsztyn – Kortowo the alert level was not achieved, and the boundary level exceeded the maximum flood by 13 cm only. This can be explained by the fact that the Łyna river in its upper course flows through the forest and lakes, which reflects a high degree of retention capacity catchment. The advantage of the sandy soil, a high number of lakes and dense trees cover much slowed down the outflow of water from the catchment during rainfall or rapid thaws. In the middle course nearby Smolajny, the level exceeded the maximum warning by about 19 cm and to the alarm level it missed only 1 cm.

In Sępopol peak level exceeded alarm level. At any gauge station peak level did not come close to the maximum ever observed.

The maximum flood flows exceeded SWQ, respectively by 1.8 m^3s^{-1} at the cross section of Olsztyn - Kortowo, 10.17 m^3s^{-1}, in the cross section of Smolajny, of m^3s^{-1}, 57.12 m^3s^{-1} in the cross section of Sępopol.

Table 4

Summary of hydrological and meteorological data for gauge station at Olsztyn – Kortowo

Date	Water level on the gauge [cm]	Temperature of water [ºC]	The average daily mean temperature [ºC]	Rain height [mm]	Snow cover [cm]
2005-03-10	58	0.1	-6.5	1.8	30
2005-03-11	66	0.4	-1.9	6.8	35
2005-03-12	66	1.0	0	4.1	40
2005-03-13	66	1.0	-4.5	0.6	41
2005-03-14	65	0.4	-1.2	0.8	40
2005-03-15	**64**	**0.4**	**0.9**	**1.6**	**40**
2005-03-16	**66**	**0.1**	**3.2**	**4.8**	**30**
2005-03-17	**66**	**1.1**	**7.5**	**3.6**	**22**
2005-03-18	**116**	**2.0**	**1.9**	**4.5**	**4**
2005-03-19	**88**	**0.4**	**-3.5**	**0**	
2005-03-20	80	0.4	-2.7	0.1	
2005-03-21	75	1.0	-3.1	0	
2005-03-22	68	0.3	-1.3		
2005-03-23	74	1.3	3.8		
2005-03-24	74	2.1	4.2		
2005-03-25	75	3.0	4.3	0	
2005-03-26	76	3.1	4.2	0	
2005-03-27	76	2.3	2.3		
2005-03-28	75	3.1	2.9		
2005-03-29	73	2.4	2.3		
2005-03-30	73	2.3	-0.2		
2005-03-31	72	3.0	0.7		

Table 5

Summary of hydrological and meteorological data for gauge station at Smolajny

Date	Water level on the gauge [cm]	the average daily mean temperature [ºC]	Rain height [mm]	Snow cover [cm]
2005-03-10	158	-8.1	3.0	26
2005-03-11	150	-1.5	4.6	29
2005-03-12	154	-0.4	1.8	34
2005-03-13	165	-6.3	1.2	30
2005-03-14	**167**	**-1.4**	**1.0**	**31**
2005-03-15	**164**	**0.4**	**1.4**	**29**
2005-03-16	**172**	**2.6**	**8.5**	**24**
2005-03-17	**178**	**6.9**	**12.6**	**15**
2005-03-18	**260**	**1.9**	**3.7**	
2005-03-19	**298**	**-3.9**	**0.0**	**5**
2005-03-20	**298**	**-2.7**	**0.2**	**4**
2005-03-21	**292**	**-2.7**	**0.0**	
2005-03-22	**299**	**-1.1**		
2005-03-23	276	2.9		
2005-03-24	272	3.4	0.3	
2005-03-25	269	3.6	0.2	
2005-03-26	270	4.2		
2005-03-27	270	1.3		
2005-03-28	264	1.4		
2005-03-29	258	1.1		
2005-03-30	254	-0.7		
2005-03-31	250	0.3		

Table 6

Summary of hydrological and meteorological data for gauge station Sępopol

Date	Water level on the gauge [cm]	Temperature of water [ºC]	The average daily mean temperature [ºC]	Rain [mm]	Snow cover [cm]
2005-03-10	180	0.1	-8.3	4.3	32
2005-03-11	195	0.2	-1.9	1.8	38
2005-03-12	199	0.2	0.1	2.8	42
2005-03-13	187	0.2	-5.5	0.3	42
2005-03-14	169	0.4	-2.3	0.7	43
2005-03-15	**163**	**0.4**	**-0.2**	**1.2**	**40**
2005-03-16	**160**	**0.6**	**1.9**	**7.9**	**38**
2005-03-17	**201**	**2.1**	**6**	**8.2**	**28**
2005-03-18	**407**	**2.3**	**0.8**	**3.7**	**15**
2005-03-19	**450**	**0.5**	**-3.8**	**1.4**	**15**
2005-03-20	**442**	**0.4**	**-2.9**	**1.5**	**19**
2005-03-21	**442**	**0.4**	**-3.6**	**0.4**	**21**
2005-03-22	**410**	**0.2**	**-1.9**		**17**
2005-03-23	**388**	**0.2**	**2.8**		**15**
2005-03-24	**366**	**2.4**	**3.4**	**0**	**9**
2005-03-25	356	2.6	2.7	0.2	
2005-03-26	355	3.4	3.1	0	
2005-03-27	356	3.0	2		
2005-03-28	349	2.8	2.7		
2005-03-29	339	2.8	1.8		
2005-03-30	320	3.1	-0.3		
2005-03-31	301	3.3	1		

On the stretch of the upper Łyna no flooding occurred, there was also no flooding over riparian areas. In the central part of the Łyna catchment no flood risk was fixed, but there were few wash-outs of river banks, flooding of the lowest located agricultural lands. In the lower part of the catchment flood risk appeared (alarm level achieved in Sępopol). The number of flooding of riversides were reported, flooding of the lowest agricultural lands as a result problems with outflow of water from tributaries of the Łyna (mainly the Guber River) increasing the extent of this phenomenon. In Sępopol basements of two buildings located in the lowest and closest part to the river were flooded.

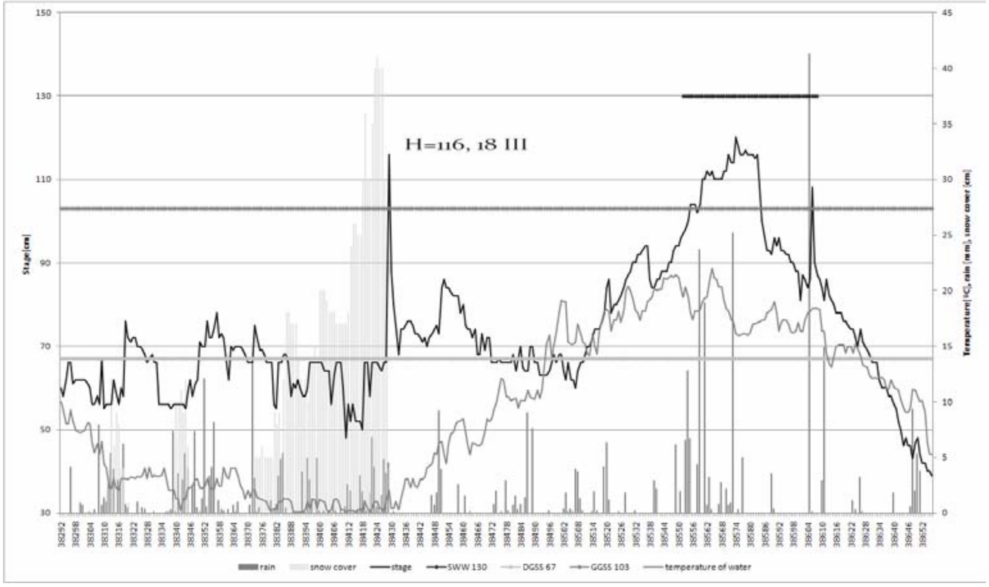

Fig. 5. Hydrograph of water level on the background of the snow cover and precipitation for the water gauge station Olsztyn – Kortowo hydrological year 2005

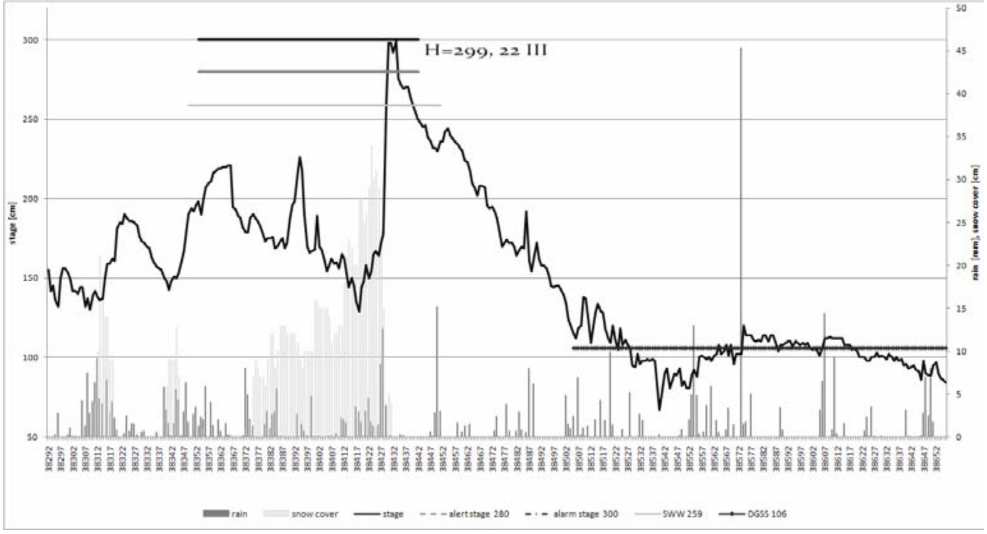

Fig. 6. Hydrograph of water level on the background of the snow cover and precipitation for the water gauge station Smolajny hydrological year 2005

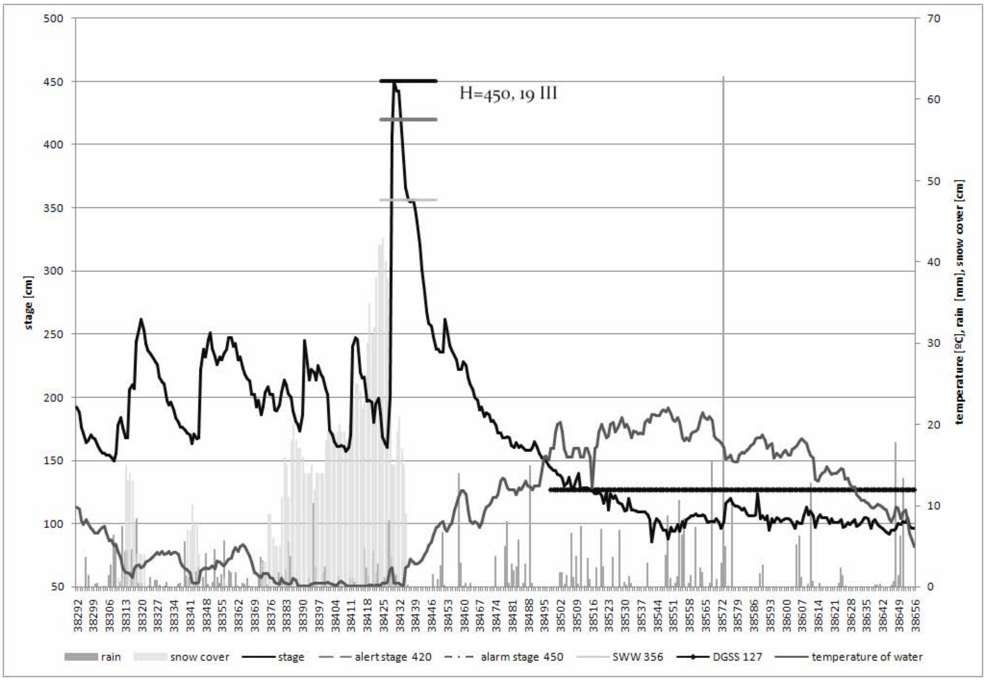

Fig. 7. Hydrograph of water level on the background of the snow cover and precipitation for the water gauge station Sępopol hydrological year 2005

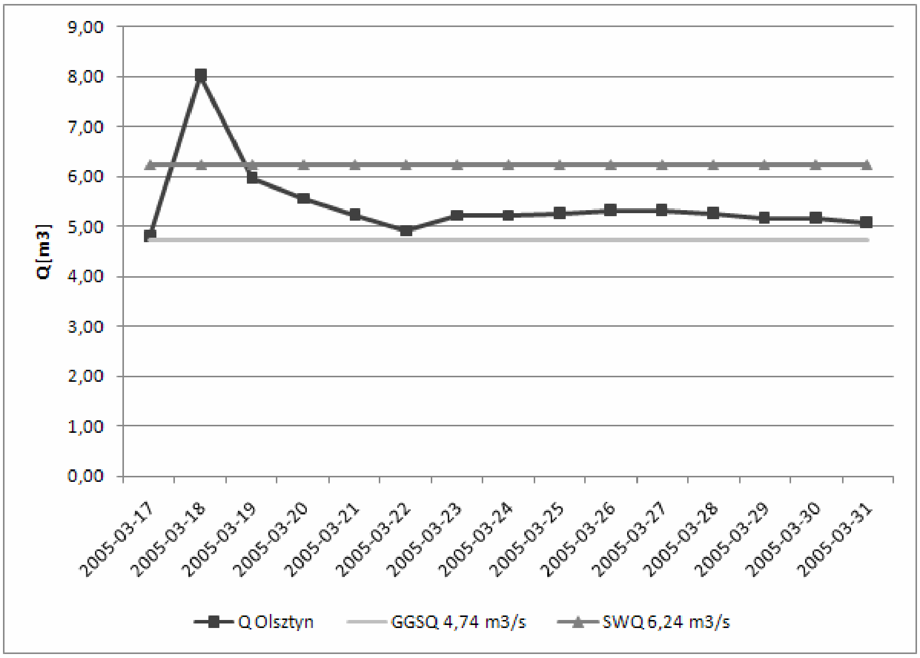

Fig. 8. The course of daily flows at gage station Olsztyn – Kortowo in March 2005

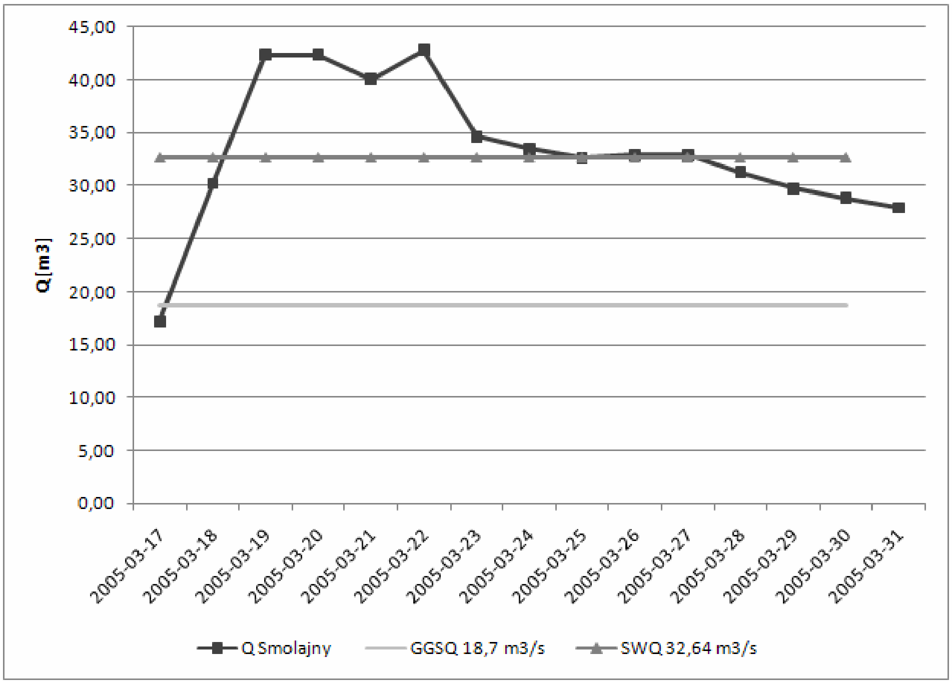

Fig. 9. The course of daily flows at gage station Smolajny in March 2005

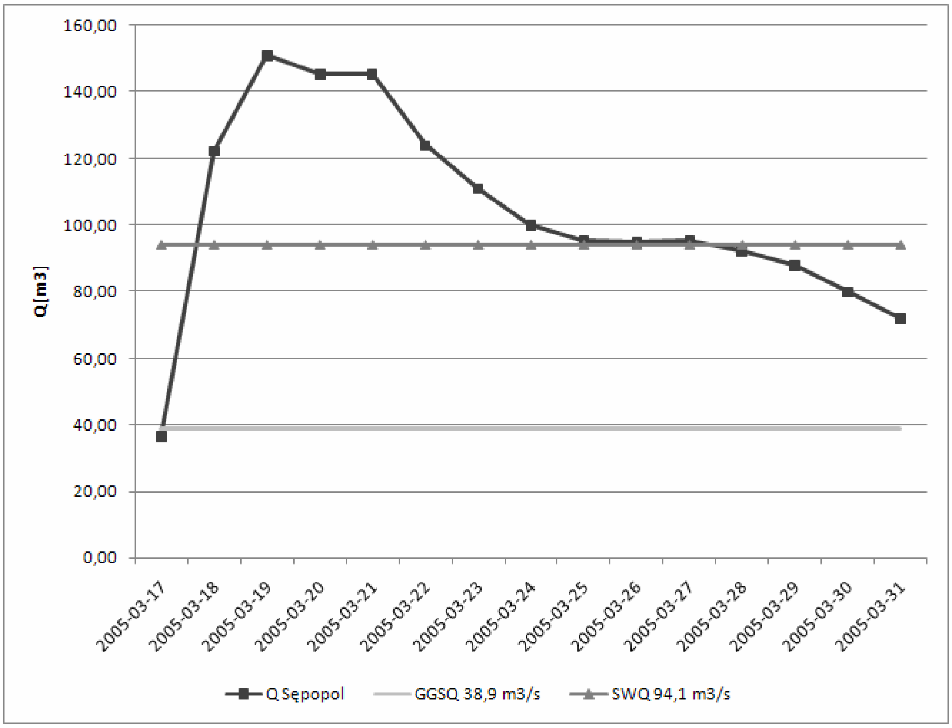

Fig. 10. The course of daily flows at gage station Olsztyn - Kortowo in March 2005

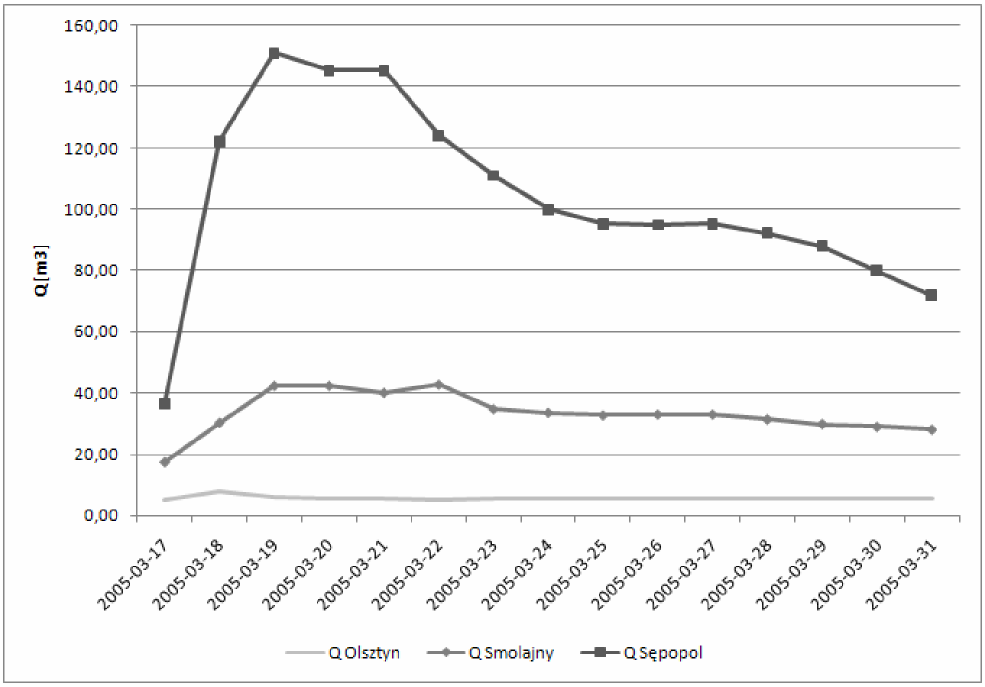

Fig. 11. Comparison of the course of daily flows on the Łyna River in March 2005

3. Summary and conclusions

The key point in hydrological research is the detection of extremes in not only a global and regional but also local scale. The regularity of occurrence of hydrological periods of high and low waters are affected both by natural factors and human activities. The specific physiographic properties of a catchment determine the behavior of individual drainage conditions for each river. Therefore, the response of post-lake rivers towards the supply from melting snow, as the main type of genetic surges, is varied and depends on both the size and configuration of the basin. The presented example of the Łyna river with its young- glacial catchment shows that the threat of flooding and the extent of the negative impact of floods increases with the river lenght. Snowmelt flooding in the upper Łyna catchment (in Olsztyn – Kortowo cross section) are mild, do not pose a flood risk due to the large capacity of water retention basin (predominance of the surface covered with sandy tracks, forests and a high proportion of the surface of lakes).

The analysis of a single high flood that occurred on the Łyna in March 2005 showed uneven response of the river, in the upper middle and lower part of the catchment, the sudden warming and the rapid melting of snow cover with a simultaneous occurrence of heavy rainfall. While the hydrometeorological conditions have not created the flood risk in the upper reaches of the river, in the middle there are floodings of local areas in the floodplains, mostly uncultivated, meadows and pastures. In the lower part of catchment there occurred flooding of several areas adjacent to the river and its tributaries. The significant impact on water levels and flows observed at Sępopol cross section is also backwater of Łyna's largest reservoir in Pravdinsk (Kalingrad Oblast). The Łyna has reached the maximum levels 3 days after the appearance of positive air temperatures, whereas in Sępopol and Smolajny profiles the water level dropped below the limit level after 10 days of flooding.

The analysis of hydrometeorological data obtained for the Łyna catchment area shows that snowmelt floods are the primary genetic floods on young-glacial areas. Their size depends on a rate of melting of snow cover. Conditions conducive to the emergence of such phenomena is warming above 0°C with the simultaneous occurrence of rain on the still frozen ground, which causes rapid surface runoff. Moreover, the greatest impact on the supply conditions of riverbeds on young-glacial areas during spring are moisture resources in the year before snowmelt flooding.

Changes in hydrometeorological elements, in particular, their cycles and trends, can be an important indicator of trends and predictability of river runoff. In the future, be expected snowmelt floods of similar or larger scale should be expected in the lake area which probably will force the updating of flood hazard maps. In the light of the requirements of the EU Flood Directive (flood hazard maps, flood risk maps, flood risk management plans), the future hydrological extreme events should not cause danger to human life and material losses should be minimised.

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