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ScienceDirect

Procedia Engineering 162 (2016) 91 – 97

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Efficient & Sustainable Water Systems Management toward Worth Living Development, 2nd EWaS 2016

Floods on the territory of Polesie

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Abstract

The article presents the analysis of the formation of floods in Polesie on the r. Pripyat during the period of instrumental observations. Polesie is a unique physiographic region, located on the territory of four countries: Belarus, Poland, Russia and Ukraine. The total area is about 130 thousand km^2. The Pripyat, the main river of Polesie, is an average river according to the European scale. The length of the r. Pripyat is 761 km; the catchment area is 173.7 thousand km^2. The article describes the most outstanding floods. The basic measures to reduce the negative effects of floods and priorities for floods research in Polesie are outlined.

Peer-review under responsibility of the organizing committee of the EWaS2 International Conference on Efficient & Sustainable Water Systems Management toward Worth Living Development

Keywords: Polesie; Pripyat; flood; risks.

1. Introduction

Polesie is a unique physiographic region, located on the territory of four countries: Belarus, Poland, Russia and Ukraine. The total area is about 130 thousand km^2 The Pripyat, the main river of Polesie, is an average river according to the European scale. The length of the r. Pripyat is 761 km, the catchment area – 173.7 thousand km^2. Spring high water is a characteristic phase of the natural hydrological regime of the rivers of Polesie. They are accompanied by

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1877-7058
Peer-review under responsibility of the organizing committee of the EWaS2 International Conference on Efficient & Sustainable Water Systems Management toward Worth Living Development
doi:10.1016/j.proeng.2016.11.020

floods of the river, which at the maximum water level rise acquire the character of catastrophic events, leading to the flooding of human settlements, agricultural land, destruction of bridges, roads, etc.

According to many scientists, in the next few years, the number of natural disasters in the world will increase. This is primarily due to climate change and population growth. According to the UN statistics, floods account for 26 % of the total number of victims and 32 % of the value of the damaged property [1]. Floods rank the first among natural disasters on the repetition, covered areas and damage to property. Growth of the losses in economy inflicted by flooding is associated with an increase in the intensity and frequency of floods due to the intensification of the economic use of water catchment areas, river valleys and floodplains [2, 3]. However, there is still no reliable long-term forecasts of the appearance of floods, reliable and generally accepted calculation methods of the damage caused and generally accepted concept of protection.

2. Methodology

The methodological basis of the study were the scientific statements about the stochastic nature of variability of floods, which made it possible to use modern statistical methods to analyze time series. The methods of water and heat and power balance of the underlying surface and mathematical modeling were used. System analysis of the accumulated information and comparative geographic method yielded the most important key points of space-time fluctuations of floods.

The standard observational data on hydrometeorological network were used as the basic material, as well as library materials of different organizations and institutions during the period of instrumental observations, maps and literature references.

3. Results

The flood in the spring is formed each year as a result of snowmelt and rainfall during snowmelt. For the rivers of Polesie, it usually begins in the first half of March, but in some years it can be shifted to February or April. Average long-term duration of flooding of floodplain is 80-110 days, and in some years it can be up to 150-180 days. The width of the spring flood on the Pripyat varies from 5 to 15 km and in some areas it is 1-2 km, the largest is in the area of town of Pinsk and reaches 30 km. The dependence of the flooded area of the floodplain of r. Pripyat on different probabilities of exceedance level is shown in Table 1 [2]. The duration of spring floods on small rivers varies from 40 to 45 days. The depth of spring flooding is typically 0.3-0.8 m, sometimes up to 2-2.5 m [4]. The most endangered by floods areas are the catchment area in the middle and lower reaches of the r. Pripyat. This is due to a narrowing of the floodplain to 6-8 km in the area of Turov and up to 1.5-2 km near the Mozyr, as well as the sharp increase in lateral inflow. On this site such large inflows as the r. Goryn (catchment area 27,000 km^2), the r. Sluch (5350 km^2), the r. Ubort (5820 km^2), the r. Ptich (9480 km^2) fall into the Pripyat.

Table 2 presents the water flow of 10 most significant spring floods on the r. Pripyat.

Table 1. Surface of flooding of the floodplain of r. Pripyat

The probability of exceedance of the level, %	1	5	10	25	50
Flooded area, thousand ha	579	550	487	404	197

Table 2. Maximum water flow (*Q*) of floods of r. Pripyat (the town Mozyr) and their probability of exceedance (*P*)

Year	1845	1877	1895	1888	1889	1940	1979	1932	1970	1958
Q, m^3/s	11000	7500	5670	5100	4700	4520	4310	4220	4140	4010
P, %	0.8	1.6	2.3	3.1	3.9	4.7	5.4	6.2	7.0	7.6

The maximum flow of the spring flood on the r. Pripyat was noted in 1845. That year an extremely high spring flood on a large area of Eastern Europe was formed [5].There was a significant autumn water accumulation in the Pripyat basin. Rivers with deep water were covered with ice while there were extensive floods in the marshes and on the surrounding areas. Winter in 1844 started unusually early. November and December, and February (1845) were unusually cold and the whole spring, until May inclusive, was constantly cold. With this duration, that winter was characterized by abundance of snow across the whole of Eastern Europe. In addition, a substantial replenishment of snow cover occurred during the February blizzard that lasted several days and covered a large area, especially the Pripyat catchment. Spring started late and it was powerful, with the vegetation development delayed by almost a month. In April the warm clear weather set in, which increased intensity of snowmelt and led to a rapid increase in water availability. Moreover, during strong warming there were heavy rains, which increased the snowmelt that caused the formation of very high water levels and a sharp increase in water flow in the river basin. The maximum level of 1845 exceeded zero graphics of modern gauging from Mozyr by 675 cm, which was 187 cm higher than the maximum level in 1932. In such a case, the water flow rate obtained indirectly by G.I. Shvec, was estimated as 11,000 m3/s with flow module being 113 L/(s·km2) [6]. Taking into account the height of the maximum level in 1845, the conditions of formation of the flood, and available historical data, it can be assumed that the height of that flood was not exceeded from the end of the XIV century to the present time. The maximum level and the Pripyat flow during flood in 1845 can be considered repeating approximately no more than once every 800 years [7, 8].

The last outstanding spring flood observed on the r. Pripyat River in 1979. By the beginning of spring snowmelt water reserves in the basin of the r. Pripyat exceeded the rate of 1.5-2 times, which contributed to the formation of a very high tide on the r. Pripyat and its tributaries. In Mozyr highest level was 2 % of the probability of exceedance, being higher than the long-term average for 2.26 m. During the whole period of observation the highest levels seen on r. Gorin and its tributary the r. Sluch were close to the extreme. The flood in 1979 caused great damage to the national economy [4].

The list of floods in Polesie is presented in table 3.

Table 3. Years with floods of different degree during the spring

River-hydrological post	Flood character		
	catastrophic, P<1 %	extending, P=1 – 2 %	big, P=3 – 10 %
Pripyat – Pinsk	-	1979	1999
Pripyat – Koroby village	-	1958	1957, 1966, 1979
Pripyat – Turov	-	1979	1932, 1940, 1956, 1958, 1970
Pripyat – Chernichi village	-	1999	-
Pripyat – Petrikov	-	1979	1931, 1932, 1940, 1956, 1958, 1966, 1970, 1999
Pripyat – Mozyr	1845	1888, 1895, 1979	1886, 1889, 1907, 1924, 1931, 1932, 1934, 1940, 1956, 1958, 1966, 1970, 1999
Pina	-	1979	1928, 1932, 1940, 1958
Yaselda – Senin village	-	1999	1958, 1979, 1981
Goryn – Rechica	-	1956	1966, 1979, 1996, 1999

Table 4 presents maximum dangerous water levels of spring floods during the period of instrumental observation of the r. Pripyat basin rivers [4].

In the last years of the last century, the maximum water discharge of spring flood was below average, which is statistically significant at the 5% significance level.

The second most important, after the spring flood, are rain floods, dangerous hydrological phenomena, bringing huge calamities from destruction, flooding human settlements, industrial facilities and agricultural land, taking lives.

Maximum flow of the rain floods are formed, as a rule, by heavy rains, as the showers at the same time do not cover the entire territory of the catchment. Rain flooding, unlike floods, occur irregularly and the magnitude of maximum flow and floods layer are usually significantly smaller than the maximum of flood. However, the rain floods in 1952, 1960, 1974, 1993, 1998 in many watercourses and alignments on the most of the Pripyat basin exceeded the spring flood, and caused considerable damage to the national economy, since they seriously affected farmland and other developed areas. Even local flooding of considerable intensity on the left bank and right-bank tributaries are able to cause significant rises in the level of the lower reaches of the Pripyat due to advancement down of the flood wave. The height of the rain floods in the middle and lower reaches of the Pripyat 2.0-3.5 m above the level before the flooding.

In relation to climate change, since 1988 on the rivers there are more cases when the highest level for the year was observed not during the spring flood but during the summer flooding and more often during winter flooding. For example, the post of Mozyr on r. Priapyat of 118 years of instrumental observations noted 19 cases in which the highest annual level was not found during the spring flood but during the summer and winter flooding, and 9 of them are recorded in the last 13 years. In the most rainy years (1908, 1917, 1927, 1928, 1923, 1952, 1979) the rivers of Polesie held 3-4 floods in the season. The average duration of the summer floods is about 15 days. Table 5 shows the most dangerous flood water levels on the r. Pripyat in the period of instrumental observations.

There has been one high summer-autumn flood every 4-6 years over the past 50 years, bringing the most significant damage to agriculture and other sectors of the economy. The most striking high water flooding of recent years was in 1993.

Table 4. Maximum dangerous water levels during spring flood on r. Pripyat and its tributaries during the period of instrumental observation

River-hydrological post	Level, sm			
	dangerously high, (probability of exceedance, %)	maximum, (probability of exceedance, %)/ date	maximum of ice float/ date	maximum duration, days/ year
Pripyat – Pinsk	250 (43)	302 (1) 29.03.1979	302 29.03.1979	50 1980, 1981
Pripyat – Koroby village	420 (40)	486 (2) 20.04.1958	460 31.03.1979	32 1979
Pripyat – Turov	340 (22)	410 (1) 02-03.04.1979	405 31.03.1979	28 1979
Pripyat – Chernichi village	520 (57)	637 (2) 21-22.03.1979	637 21-22.03.1999	46 1999
Pripyat – Petrikov	800 (45)	933 (1) 03-04.04.1979	924 01.04.1979	40 1999
Pripyat – Mozyr	550 (30)	742 (1) 22-24.04.1995	670 21.04.1931	31 1941
Pina - Pinsk	335 (8)	366 (2) 01.04.1979	347 29.03.1979	12 1979
Yaselda – Senin village	195 (37)	247 (0,9) 27.03.1999	234 06-12.031999	127 1999
Goryn – Rechica	530 (52)	635 (2) 11.04.1956	635 11.04.1956	26 1979

Table 5. Maximum dangerous water levels of the rain floods during the period of observation

River-hydrological post	Levels, cm					
	winter flood			rain flood		
	maximum	date	probability of exceedance, %	maximum	date	probability of exceedance, %
Pripyat – Pinsk	284	15.01.1981	1	–	–	–
Pripyat – Koroby village	431	08.01.1975	2	439	19–23.11.1993	2
Pripyat – Turov	–	–	–	–	–	–
Pripyat – Chernichi village	–	–	–	520	08–11. 08.1993	4
Pripyat – Petrikov	826	12–13.1.1981	1	829	02, 05.05.1975	2
Pripyat – Mozyr	–	–	–	–	–	–
Pina - Pinsk	–	–	–	–	–	–

Yaselda – Senin village	221	19.12.1980	2	203	30.11–17.12 1990, 1995	1
Goryn – Rechica	550	29.01.1948	2	567	31.07.1993	3

In the second and third decades of July 1993 in a number of districts of Brest, Gomel and Minsk regions 2.5-3 monthly norms of precipitation fell. The most unfavorable situation developed in Zhitkovichi and Stolin districts, as increased amounts of precipitation fell in June (about 1.5-2 monthly norms), and in July, rainfall was observed in the form of heavy rains of rare recurrence. The daily maximum on 23 of July in Zhitkovichi region was 57 mm, and 115 mm in Stolin. It should be noted that during the night of 24 of July on the territory of Stolin region 67 mm of precipitations fell. This amount of precipitation was the largest during the entire observation period. As a result of the catastrophic precipitation waterlogging of the root layer of soil occurred and rain flood in the rivers of Polesie was formed. The terms of the formation of rain flood were affected by large amount of rain that had fallen in Zhytomyr and Rivne regions of Ukraine. The start of the rise of water levels on the r. Pripyat and its tributaries was observed on 12-15 of July. Maximum levels of the rain floods on small rivers were already formed on 28-30 of July, at the r. Goryn on 31 of July, and on the r. Pripyat in mid-August. The highest floods were formed by small streams and of the r. Goryn and the r. Stviga. They are comparable with the maximum levels of spring flooding of rare recurrence by its magnitude. The exceeding of the maximum levels of rain floods over low-flow for the r. Pripyat was about 3 m, and on the r. Goryn – 3.4 m, on the small watercourses 2.0-2.5 m. Elevated levels caused flooding of large areas. The hydrological situation was complicated by the fact that the flood was formed in the period of greatest grass and shrubby vegetation of the riverbeds and floodplains. Increased roughness of the channels and floodplains of watercourses caused not only a high rise in water levels, but also significantly slowed their decline in August. In Pripyat itself due to water inflow from tributaries increased levels lasted until mid-August. Synchronicity of the flood on the left and right bank tributaries determined the development of significant flooding in the lower reaches of the r. Pripyat, corresponding to 2% probability of exceedance.

Studies have shown that changes in the flows of Polesie rivers under the influence of natural oscillations (global warming) and anthropogenic influences (large-scale changes in land reclamation) have the following trends. Since the mid 60s of the last century, average and minimum water consumption have a strong tendency to increase, at the same time, the maximum water discharge of spring flood decreases somewhat, as it is confirmed by the normalized difference integral curves for the r. Pripyat-Mozyr [4].

Assessment of periodicity of maximum spring flood water flow on the r. Pripyat-Mozyr was carried out on the basis of spectral-temporal analysis (STAN) with window length of 35 years, as well as parameter randomization. Analysis of STAN diagrams showed that the r. Pripyat-Mozyr post is characterized by the following short-term cycles lasting about 2 (1910-1946), 3 (1930-1962), 4 (1910-1980), 6 (1900-1910), 8 years (1916-1942 years), as well as long-term cycles – 20 (1936-1978), 33 years (1928-1976).

It can be assumed that the main cause of the decrease in the maximum levels of the spring flood water of the Pripyat river basin is of a natural character, and to a lesser extent related to anthropogenic influences. On the other hand, large-scale land reclamation in Polesie led to the draining of large bogs, tree and bush removal and transformation into agricultural land which causes higher flood. Thus, we can assume that in the river basin of Pripyat there was a compensation of two divergent vectors. Nevertheless, the natural factors caused by global fluctuations in the hydrothermal regime are predominant. It can be hypothesized that in the absence of reclamation even greater reduction in runoff could happen on Polesie, which would have a negative impact on riverine ecosystems.

The consequences of catastrophic floods have shown the urgency of flood management in Polesie.

Projected climate warming and the inevitable increase in the economic development of river valleys, due to population growth, will undoubtedly lead to an increase in the frequency and destructive power of floods. It is therefore necessary to strengthen research, organizational and practical work aimed at reducing the damage from floods. Prevention of natural disasters reduces costs of elimination of the impact of flooding in 50-70 times.

Analysis of the current flood management system, its operation experience and the impact of the flood of 1999 showed that implementation of the engineering methods alone does not provide the suitable level of flood security in case of effective economic use of the floodplain. It is necessary to combine engineering methods of protection (flow regulation by reservoirs, dams bund riverside areas, straightening and deepening the river bed in order to accelerate the flow of flood waters, construction of canals to divert water into the natural depressions of the relief, bedding areas, and others) with non-engineering methods. The latter include the development of economic and legal norms for the use of the territories endangered by floods. These norms primarily include: the restriction or total prohibition of the types of economic activity, which may result in increase of floods, as well as the expansion of activities aimed at creating conditions for reduction in flow. In addition, such economic activities, which are the least vulnerable to flooding should be implemented. Engineering structures of land and commercial facilities protection must be reliable, at the same time their implementation should be associated with minimal disruption to the environment.

For the development of flood control measures the whole catchment area, rather then its individual sections in the river valleys, should be considered, as local flood management does not take into account the whole situation of the flooded area, does not provide economic benefit, and may significantly worsen the situation and result in even greater damage from floods.

For the economic development of areas endangered by floods detailed technical and environmental studies should be carried out in the river valleys, in order to identify ways to obtain the greatest possible economic effect of the development of the territories and at the same time to minimize the potential damage from floods. Resolving the issue is impossible without the development and further improvement of methods for calculation of both direct and indirect damages caused by floods. The objective estimation of damage is crucial for the correct choice of strategy and tactics to prevent this disaster. An accurate assessment of the actual and potential losses both during and after flooding allows to choose the optimal variant of measures to prevent and eliminate the damages caused by floods. Estimation of damages is very important, in particular, to assess the feasibility and effectiveness of environmental protection engineering systems, as well as the security of the population and legal entities.

Flexible program on flood insurance, which combines both mandatory and voluntary form may be the best tool to manage land use on territories endangered by floods.

There should be an operatively acting system on flood forecasting and notification of the population about flood onset time, and the maximum possible level, and duration in days. Flood forecasting should be based on the development of the general services of observation of the hydrometeorological conditions (it should be noted that a significant reduction in the number of hydrometeorological observation posts occurred in recent years). It is necessary to provide hydrometeorological services with modern equipment, automated data collection and processing systems, to expand the use of radars and satellites.

The situation with information on the r. Pripyat is rather complicated. This is primarily due to the need for assessment of the river runoff over a large number of individual tributaries (from the territory of Ukraine) and with limited hydrological observations on the border. After the flood of 1999, the new hydrological observation posts were opened, but they can not fully solve the problem.

Serious attention should be given to advance information about the flood probability, explaining the possible consequences and the necessary measures in the case of flooding. In areas endangered by floods propagation of knowledge about floods should be widely deployed. An action plan for measures before, during and after the flood for state services and citizens should be developed.

Clear zoning and mapping of floodplains with drawing the boundaries and magnitude of floods are needed. Considering the type of the economic use of the area it is recommended to isolate areas with 20% probability of flooding of agricultural land, 5% – for the buildings in the countryside, 1% - for urban areas and 0.3% – for railways. It goes without saying that the number of zones and the principal of zoning can vary to some degree depending on the nature and ecology of the area. However, almost all areas of the floodplain, flooded more than once every 5 years, can only be used for mowing hay.

Particular attention should be paid to the impact of artificial change of the conditions of formation maximum runoff on the hydrological and hydraulic parameters of flow, as well as to predicting the extent of flooding and the development of management strategies to minimize the negative impacts of floods, identifying ways of the efficient use of floodplains with high economic potential.

4. Conclusions

In the field of flood study and control the priorities are [9, 10]:

- Zoning and mapping of floodplains with drawing the boundaries of floods water availability, taking into account an economic use of the territory;
- Development of a mathematical model and databases for flood forecasting;
- Development of flood protection in the river valleys, taking into account the entire watershed;
- Identifying types of economic activity that would suffer minimal damage from flooding;
- Development of engineering flood protection facilities for agricultural land and commercial facilities with minimal disruption of natural ecosystems;
- Optimization of combinations of engineering and non-engineering methods for protection of settlements and farmland (economic and legal).
- Flexible program of flood insurance combining mandatory and voluntary forms;
- Development of alerting systems for public about flood onset time, maximum possible level and duration;
- Development of a uniform methodology for assessment of consequences of the flooding and account of damage, assessment of impact to human health during flood period and after.

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