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CONSIDERATIONS ON FLOODS IN THE PRUT–BÂRLAD BASIN

BY

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Abstract. The work presents an analysis of historical floods and areas with potentially significant risk to floods, in the Prut–Bârlad river basin, as well as measures to reduce flood risk. Over the years, floods have had significant consequences for human activity, the environment, cultural heritage and economic activity. In order to reduce flood risk, various programmes for tracking hydrometric and hydrometeorological parameters have been created, critical defence work has been fixed, the warning system has been implemented-alarm, the defence plan has been updated against floods, critical points were inventoried on water courses and hydrotechnical constructions. In order to assess flood risk, hazard maps have been drawn up in 3 flood scenarios with different probabilities, as well as flood risk maps using hydrological and hydraulic modelling. In order to reduce the risk to floods, at European level, emphasis is placed on non-structural measures: measures to reduce the probability of flooding (reduction of hazard) and measures to increase resilience to floods.

Keywords: defense, hazard, measures, risk reduction, warning.

1. Introduction

Floods are natural phenomena that spread widely both nationally and globally, which, by their scale and frequency, mark the development of human

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society, and are among the largest producers of human victims and damage. Studies conducted at European level show an increase in disasters caused by flash floods between 1950 and 2006. These events typically affect basins smaller than 1000 km^2 with response times of a few hours or less (Marchi *et al*., 2010).

Flooding has become a growing topic of concern for authorities and citizens, given that, over the past 15 years, the number of floods in European river basins has increased from 11 to 64 per decade (Brinke *et al*., 2017).

A study carried out by Dragomir *et al*., on some small hydrographic basins in Romania showing that a high percentage of the river network is characterized by a high and very high flood potential (Dragomir *et al*., 2020). Over the years, it has been demonstrated that these phenomena cannot be avoided but can be managed in order to reduce the damage by taking specific measures and actions. Thus, the term "flood risk management" has emerged, proposing a number of policies, procedures aimed at identifying, analysing, assessing, treating, monitoring and re-evaluating risk, taking into account that there is no total flood protection.

At the country level are present numerous works to protect people and property, resulting in: dams (length 9920 km), regularization of whites (6300 km), 217 non-permanent accumulation lakes with flood-attenuation volumes of 893 mm^3 (e.g. Ibăneasa Accumulation, Botoșani) 1232 permanent accumulation lakes with flood attenuation volumes of 2017 mil. m^3 (e.g. Izvorul Muntelui Dam, Neamț.). The change at the European level of the concept of regularization of watercourses has imposed changes in the way of designing and making constructions in the river bed and riparian zone. This is how the concept of "green regulation" came about (Luca and Tamaş Avram, 2021).

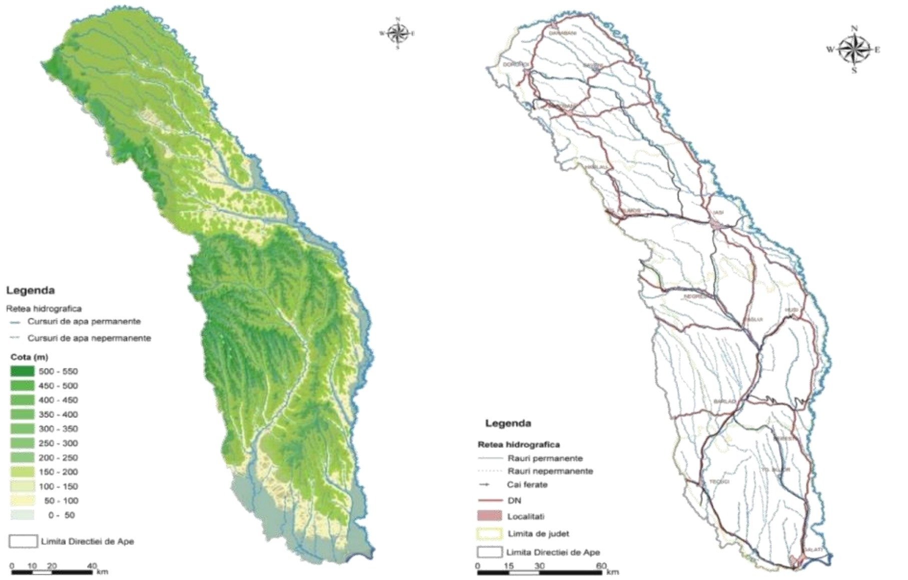
At international level, some of the most significant defense works are in the Netherlands - the defense system "Delta Construction" and Zimbabwe - the largest accumulation, carried out by the Kariba dam on the Zambezi River (180 km^3) (Steiner, 2009).

2. Geophysical Data of the Prut–Bârlad Hydrographic Space

The Prut–Bârlad hydrographic area is located in the northeastern extremity of the Danube basin, with an area of 20,569 km^2, on the territory of Romania. The hydrographic network of the Prut–Bârlad hydrographic area consists of 80% non-permanent courses, and the drought phenomenon is possible. The total length of the hydrographic network related to the space administered by the A.B.A. Prut–Bârlad is 10,280 km. The main relief area present in the Prut–Bârlad hydrographic space is the plain, with limited areas of the plateau, with a temperate continental climate and average annual precipitation between 400 mm and 600 mm per year (A.B.A. Prut–Bârlad, 2023).

The Prut River basin has an elongated shape with an average width of approx. 30 km, with springs in the Carpathian Forest Mountains of Ukraine. The hydrographic network has a length of 4,551 km and a density of 0.413 km / km^2. In this basin there are variations of altitude, from 130 m in the central area, to 2 m in the confluence area (A.B.A. Prut–Bârlad, 2023).

The main tributaries of the Prut River, out of the 248, are: Başeu (S = 965 km^2, L = 118 km); Jijia (S = 5757 km^2, L = 275 km); Sitna (S = 925 km^2; L = 65 km); Miletin (S = 663 km^2; L = 87 km); Bahlui (S = 959 km^2; L = 110 km); Chineja Valley (S = 766 km^2; L = 73 km), (on the right side), and on the left side are: Telenaia, Lopatnic, Racovețul, Frasinul (A.B.A. Prut–Bârlad, 2013).



a b

Fig. 1 – Geophysical characteristics in BH Prut–Bârlad: a – relief map; b – hydrographic map (A.B.A. Prut–Bârlad, 2013).

The Bârlad hydrographic basin has a reception area of 7,220 km^2 and a length of the 2,565 km hydrological network. The most important tributaries of the Bârlad river are: Racova (L = 49 km, S = 329 km^2), Vaslui (L = 81 km, S = 692 km^2), Crasna (L = 61 km, S = 527 km^2), Tutova (L = 86 km, S = 687 km^2) and Berheci (L = 92 km, S = 1021 km^2), (A.B.A. Prut–Bârlad, 2013).

In the Prut–Bârlad hydrographic area, there are 72 important accumulations, with an area of more than 0.5 km^2, of which 42 have complex use, with a total useful volume of 614.38 mil.m^2. There are 9 natural lakes, of which 7 are in Galați County (A.B.A. Prut–Bârlad, 2013).

The stock of water resources consists mainly of the Prut and Bârlad rivers and their tributaries, totalling 3,661 million m^3 / year, of which about 960 million m^3 / year is used.

3. Results and Discussions

Climate change over the last 30-40 years is felt, in particular, in the annual and in the territory of precipitation and by their zonal intensity (Avram (Tamaş) and Luca, 2022).

At the international level, research is being carried out to find the best methods of reducing the risk of floods. Thus, Yang *et al*. researched a new method of measuring river levels involving a video surveillance system. This method provides instant river stage figures and on-site videos so that disaster prevention measures can be implemented accordingly (Yang *et al*., 2014). Another method of flood risk reduction is the use of remote sensing data to generate and evaluate a floodplain hydraulic model (Wright *et al*., 2008).

In order to avoid the placement of works inappropriate for water management, in the hydrographic space, as well as for the protection of the environment, ecological restoration, for taking adequate defense measures against floods, it was necessary to know the protected areas and the wetlands.

The categories of protected areas, according to the requirements of the Framework Directive and the Water Law are:

- protection areas for water withdrawals for drinking water;
- areas for the protection of economically important aquatic species;
- areas intended for the protection of habitats and species where water is an important factor;
- nitrate vulnerable areas have been identified in 30 municipalities.

The wetlands are 262, of which 172 in the Prut River basin and 90 in the Bârlad river basin (A.B.A. Prut–Bârlad, 2013).

Over the years, in the Prut–Bârlad hydrographic area, there have been numerous floods, the most significant being the ones from 1965, 1969, 1970, 1985, 1991, 1998, 2005, 2008 and 2010, which occurred as a result of excessive precipitation, from May, June, July. Another cause of these events is the deforestation of small watersheds (Romanescu and Nistor, 2011). The floods produced have led to maximum flows in certain sections (A.B.A Prut–Bârlad, 2023):

- 1965: 2240 m^3 / s on the Prut River at Rădăuţi–Prut, ca. 200 m^3 / s on the Bârlad river at Negrești, Vaslui and Bârlad;

- 1969: 731 m^3 / s on the Prut River at Rădăuţi–Prut, 394 m^3 / s on the Jijia river at Todireni, ca. 300 m^3 / s on the Bârlad river at Negrești and Vaslui and 380 m^3 / s at Tecuci;

- 1985: 1250 m^3 / s on the Prut River at Rădăuţi–Prut, 212 m^3 / s on the Jijia river at Todireni, ca. 390 m^3 / s on the Bârlad river in Negrești and 250 m^3 / s in Vaslui;

- 1988: 1780 m^3 / s on the Prut river in Rădăuţi–Prut, 104 m^3 / s on the Jijia river in Victoria;

- 1991: 1050 m^3 / s in May and 633 m^3 / s on the Prut River at Rădăuţi–Prut, 200 m^3 / s on the Bârlad river at Vaslui and Tecuci;

- 2010: 2137 m^3 / s, in June - July on the Prut River in Rădăuți–Prut.

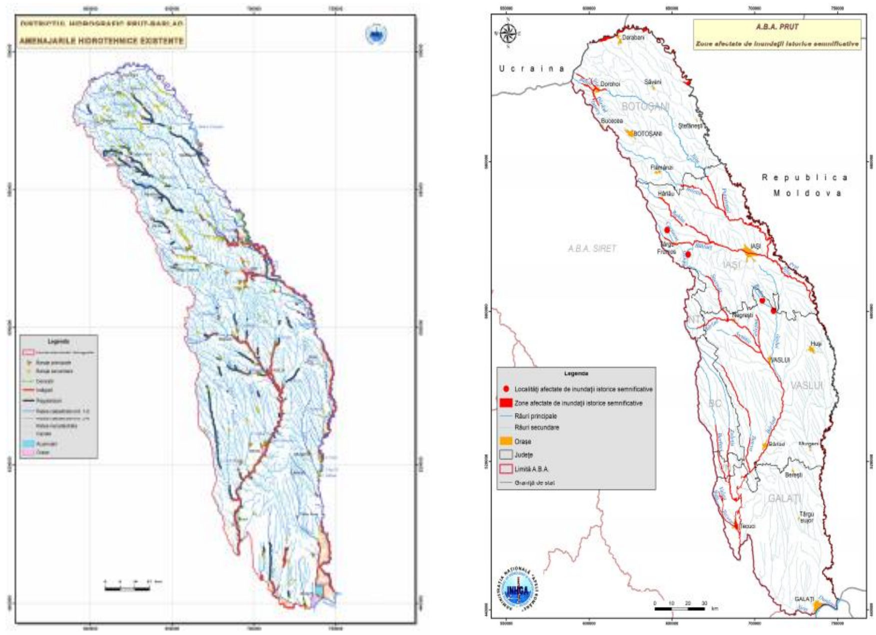


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Fig. 2 – General view of the Prut–Bârlad basin: a -hydrotechnical arrangements; b - localization of areas with potentially significant flood risk (A.B.A. Prut–Bârlad, 2013).

These floods have caused numerous damages to the human society, the environment, the cultural heritage and the activity of the society. For example:

- at the 2005 floods, there were 200 affected localities;

- at the floods of 2009 there were registered 6,000 houses and annexes affected households, 70 affected socio-economic objectives;

- at the floods of 2010 there were 700 affected roads;

- at the floods of 2012 there were 35 affected socio-economic objectives;

- at the floods of 2013 there were 350 affected localities, 1,500 houses affected and 1,100 affected roads;

- at the floods of 2014 there were 190 affected localities and 600 affected roads;

- at the floods of 2016 there were 380 affected localities and 1,100 houses affected (A.B.A. Prut–Bârlad, 2023).

Floods over time have led to various situations, such as: severe soil erosion, mudslides, which affect communities, massive deforestation, very fast surface leaks, poor quality water due to uncontrolled chemical discharges and sediment erosion, reduced water resources in summer.

The main flood protection works in the Prut–Bârlad hydrographic area are (A.B.A. Prut–Bârlad, 2013):

- the accumulation lakes that also have the role of flood control are 393, of which 23 are non-permanent, with a volume of 112.8 mil.m^3 and 370 complexes with a total mitigation volume of 1,139 mil.m^3;

- embankment works carried out in the Prut River basin: 46 works with a length of approx. 467.8 km (267 km on the Prut River), and in the Bârlad River basin 78 with a length of 566 km;

- the works of regularization and protection of the shores are distributed as follows: in the Prut River basin, 80 regularizations over a length of 360 km and 105 shore defenses for approx. 52 km, and in the Bârlad River basin 102 regularizations on approx. 540 km and 49 shore defenses on approx. 20 km.

The Prut–Bârlad Basin Water Administration, as well as the other basin administrations, have developed various programs and projects, according to the legislation in force (Flood Directive 2007/60 / EC), in order to reduce the negative consequences for human health, environment, cultural heritage and economic activity associated with floods.

Water Directive 2007/60 and C.E. and the legislation of the Romanian government emphasize the concepts of “continuous river” and “more space for rivers” (Avram, 2020).

In order to identify areas with potential significant risk to floods, the PHARE project was implemented, which shows - potentially floodable areas, in the form of extreme historical flooding and assessment of the potential impact of flooding (potential consequences).

The implementation of the flood directive was carried out in 3 stages:

- preliminary assessment of flood risk (EPRI);
- drawing up hazard and hazard maps for floods;
- implementation of flood risk management plans.

Through the EPRI exercise, historical floods were identified that had significant consequences, but also delimited the areas with potentially significant flood risk (A.B.A. Prut–Bârlad, 2023).

The second step in reducing the risk of flooding is the creation of hazard and risk maps for floods, based on hydraulic and hydrological modelling. The main elements of hazard maps are water depth and speed. The hazard maps were created for different probabilities of overcoming (0.1%, 1%, 5%, 10%), showing the extension of the flood zone. Flood risk maps are based on hazard maps and have the potential negative effects associated with them. With the help of mapping, the effects of floods with different return periods on the banks can be analysed (Salemian and Moosavi Jahromi, 2010).

The delimitation of the flood plains is an important component in the flood risk assessment of the proposed objectives (Neuhold *et al*., 2009).

Developing appropriate geohydrological hazard maps and analysis at an appropriate scale and as quickly as possible is critically important from an economic and social point of view (Romanescu *et al*., 2017).

Table 1

Areas with potential flood risk in BH Prut–Bârlad (A.B.A. Prut–Bârlad, 2023)

Hydrographic basin	Area with potentially significant flood risk
W.B.A. Prut–Bârlad	Bârlad River
W.B.A. Prut–Bârlad	Socovăț River - downstream Mădârjac
W.B.A. Prut–Bârlad	Stavnic River
W.B.A. Prut–Bârlad	Tejejna River – downstream Rășcani
W.B.A. Prut–Bârlad	Stemic River– downstream Buda
W.B.A. Prut–Bârlad	Vaslui River
W.B.A. Prut–Bârlad	Dobrovăț River - downstream Codăești
W.B.A. Prut–Bârlad	Rediu River – downstream Tăcuta
W.B.A. Prut–Bârlad	Crasna River
W.B.A. Prut–Bârlad	Simila River
W.B.A. Prut–Bârlad	Bogdana River – upstream Cepești
W.B.A. Prut–Bârlad	Tutova River – downstream Rușenii Răzești
W.B.A. Prut–Bârlad	Tutova River –downstream Ciocani
W.B.A. Prut–Bârlad	Lipova River – downstream Satu Nou
W.B.A. Prut–Bârlad	Studineț River
W.B.A. Prut–Bârlad	Berheci River – downstream Oțelești
W.B.A. Prut–Bârlad	Drobotfor – upstream Gura Crăiești
W.B.A. Prut–Bârlad	Tecucel River – Tecuci

The third stage in flood risk reduction is the flood risk management plan. The main objectives of the plan are: avoiding / preventing new risks, reducing the existing risks, increasing resilience, public awareness.

Through the flood risk management plan, various measures to reduce the negative effects, structural measures, as well as non-structural measures are required.

Structural measures represent technical measures to protect the population and material assets against floods, in order to reduce the risk or to influence the modality or probability of occurrence of the event, in particular the flow conditions and the hydrological regime of the floods (accumulations, dams, embankments, regularizations, recalibration of the watercourse, shore consolidations and bypasses). These measures have an irreversible impact on the environment, which is why they need to be taken only when the situation requires it (Şelărescu and Podani, 1996).

Non-structural measures are a series of flood prevention and protection modalities with minimal effect on the environment. They are very effective in reducing the long-term risk of flooding. Non-structural measures are classified into two categories:

1. Measures to reduce the probability of floods: works to combat soil erosion, torrents, afforestation, avoidance of new constructions in flood areas, terracing of vineyards or orchards.

2. Measures to increase the resilience to the floods: development of the informational system for warning and forecasting of the floods and of the decisional systems of operative action before, during and after the floods, establishing rules for the coordinated exploitation of all the hydrotechnical works at the level of the river basin, based on forecast information on the characteristics, duration and timing of the floods, planning and management of the area subject to flood risk, based on the analysis of hazard and risk maps on floods, introducing restrictions on the completion of new constructions in the flood zones, as well as information activities and awareness of the population at risk of flooding.

In the study conducted by Marchi *et al*. it was found that the maximum flow data from the analysed basins come from post-flood surveys in the unassessed streams. This aspect emphasizes both the importance of post-flood surveys in building and expanding flash flood databases, and the need to develop new flood hazard assessment methods capable of taking post-event analysis data into account (Marchi *et al*., 2010).

At national level, numerous projects have been proposed to reduce the risk of flooding:

1. WATMAN - Information System for Integrated Water Management - Stage I (WATMAN 1) and Stage II (E + WATMAN 2) in the 2016 - 2021 implementation;

2. RO-RISK project (continuation - beneficiary I.G.S.U.) - flood component, oriented towards determining areas with significant risk due to torrential floods;

3. Project for the completion and modernization of the national system of hydrological monitoring and dissemination of information to authorities and population;

4. Technical assistance for the implementation of Directive 2007/60 / EC for the period 2016 – 2021;

5. Technical assistance for the implementation of the Inspire Directive 2007/2 / EC in correlation with the Flood Directive 2007/60 / EC for the period 2016 – 2021 (A.B.A Prut–Bârlad, 2023).

The set of measures applicable at the level of A.B.A. includes those measures, in particular planning, monitoring and optimizing flood risk management, with an impact on the entire hydrographic area.

Examples of works to reduce the risk of flooding, at A.B.A. Prut–Bârlad:

- Redevelopment of the river Bârlad, in the area km 41 + 100 - 41+ 450, Ghidigeni commune, Galați;

a b

Fig. 3 – General view of the redevelopment works Bârlad River, Ghidigeni comm., Galați county, year 2018: a - consolidation of the left bank overgrowth; b - consolidation of the right bank loan prism (A.B.A. Prut–Bârlad, 2018).

- Ensuring the transport capacity of the regular riverbed of the Miletin river, Coșula commune, on the length of 3.5 km, Botoșani county;

a b

Fig. 4 – Overview of the transport capacity insurance works on Miletin River, Coșula commune, Botoșani county, year 2018 (A.B.A. Prut–Bârlad, 2018).

- Flood protection works, on the Suhu River, in the village Slobozia Conachi, Galați county;

a b

Fig. 5 – Overview of protection works on the Suhu River, Slobozia Conachi, Iași County, year 2018: a - vegetative consolidation; b - overhanging dams with the help of hydrobarages (A.B.A. Prut–Bârlad, 2018).

- Arrangement of the Siret River in the village of Șendreni and Șerbesti, Galați county;

a b

Fig. 6 – Overview of the Siret River, Slobozia Galaţi County, year 2018: a - lifting the fascine mattress on the Siret River, Şendreni commune; b - shore consolidation of anchorages on the Siret River, Şerbeşti commune (A.B.A. Prut–Bârlad, 2018).

4. Conclusions

Flooding is an important problem both locally and nationally, because over the years in the Prut–Bârlad river basin have caused numerous material damages and losses of human lives.

Most floods in the Prut–Bârlad river basin occurred on the Prut River in place Rădauţi and the Jijia river in place Todireni.

To assess the impact of floods in the river Prut–Bârlad were drawn up hazard maps and flood risk.

Defense measures, structural and non-structural, do not cancel out the risks to the floods, but only limit them.

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CONSIDERAȚII CU PRIVIRE LA INUNDAȚIILE DIN BAZINUL PRUT–BÂRLAD

(Rezumat)

Lucrarea prezintă o analiză a inundațiilor istorice și a zonelor cu risc potențial semnificativ la inundații, din bazinul hidrografic Prut–Bârlad, precum și măsurile de reducere a riscului la inundații. De-a lungul anilor, inundațiile au avut consecințe semnificative asupra activității umane, mediului, patrimoniului cultural și activității economice. Pentru reducerea riscului la inundații, s-au creat diverse programe de urmărire a parametrilor hidrometrici și hidrometeorologici, s-au reparat lucrări critice de apărare, s-a implementat sistemul de avertizare – alarmare, s-a actualizat planul de apărare împotriva inundaților, s-au inventariat punctele critice pe cursurile de apă și la construcțiile hidrotehnice. În vederea evaluării riscului la inundații, s-au întocmit hărți de hazard în 3 scenarii de inundabilitate cu diferite probabilități, precum și hărți de risc la inundații, folosind modelarea hidrologică și hidraulică. Pentru reducerea riscului la inundații, la nivel european, se pune accentul pe măsurile nonstructurale, respectiv măsuri de reducere a probabilității de inundații (reducerea hazardului) și măsuri pentru creșterea rezilienței la inundații.