ANALYSIS OF HYDROMORPHOLOGICAL ALTERATIONS OF THE WATER BODIES OF THE PRUT RIVER BASIN (IN LIMITS OF THE REPUBLIC OF MOLDOVA)

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Abstract: The paper contains assessment of hydromorphological state of 83 water bodies delineated in the Prut river basin in the limits of the Republic of Moldova. Analysis of hydromorphological alterations is based on the approaches and methodology proposed in Water Framework Directive and its guidelines and was realized for elaboration of Prut River Basin Management Plan. Main hydromorphological alterations, which were analyzed, are: water abstraction, impoundments/reservoir effect (interruption of the river continuity by dam construction), hydropeaking, density of irrigation canals and flood protection levees. The most significant pressure is caused by dam construction on the rivers that affects the hydrological regime of small rivers. The impounded length of 27% of all water bodies is over 30% and include them to the category *at risk* of failing the environmental objectives of Water Framework Directive. Because of lack of data some hydromorphological alterations could not be good enough evaluated and were only conceptually analyzed. This study will constitute the basis for developing Programme of Measures towards attaining environmental objectives for water bodies.

Keywords: Prut River, hydromorphological alterations, Water Framework Directive

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Introduction

One of the main tasks of Water Law of the Republic of Moldova [7] and Water Framework Directive (WFD) [6] is elaboration of River Basin Management Plans (RBMP). A key component of the RBMP represents analysis of main pressures and impact on water bodies. According to WFD three major types of pressure are distinguished: point source pollution; diffuse source pollution and hydro-morphological alterations.

Present study represents a short evaluation of state and pressures of hydromorphological alterations in the pilot area - the Prut River Basin within the limits of the Republic of Moldova.

The study area has 8226 km^2, where 83 river water bodies (RWBs) have been delineated [3, 4], with a total length of 2152 km (fig. 1). 63 of them have been identified as Heavily Modified Water Bodies. The average length of RWBs is 26 km, only 1 RWB has a length over 100 km, the average area of RWBs catchments is 99 km^2, 55 RWBs catchments have an area less than 100 km^2.

Present activities were performed within the EU project for producing an integrated transboundary River Basin Management Plan of the Prut Basin within the limits of Ukraine and Moldova realized by the Institute of Ecology and Geography of the Academy of Sciences of Moldova in collaboration with experts from Environmental Protection of International River Basins (EPIRB).

Methodology

Analysis of hydromorphological alterations is based on the approaches and methodology proposed in WFD and the guidelines for WFD implementation, Guidelines provided by project EPIBR expert group: Guidance Document addressing hydromorphology and physico-chemistry for a Pressure-Impact Analysis/Risk Assessment according to the EU WFD, Water Law 272 from 2011, by laws, Moldavian Laws, Normative Acts and Strategies.

Evaluation of pressure of hydromorphological alterations on water bodies was performed using the principle: sum of parameters. Identification of water bodies at risk of failing the environmental objectives of WFD was made using the principle One-Out-All-Out.

The overall pressure was calculated by summing up all types of pressures with specific risk criteria, done by attributing to water bodies a coefficient according to the type of risk from 1 (not at risk) to 3 (at risk). The pressure of hydromorphological alterations was assumed to be a sum of all pressures: impoundments/reservoir effect (interruption of the river continuity by dam construction), hydropeaking, water abstraction, levees and density of irrigation canals; in total it gave a sum of 15 points and respectively the RWBs of 1-5 points were attributed to low pressure, those with 6-10 points - to moderate pressure and those with 11-15 points - to high pressure.

Identification of water bodies at risk was made by attributing to water bodies the type of risk and respective colour: green, orange, red according to [1, 6]. The same approach was used when creating the maps from this article. The approach for identification

of water bodies at risk of failing the environmental objectives is the principle One-Out-All-Out [1, 6]. This approach is based on the principle that each pressure that exceeds one of the risk criteria has an effect on the risk status of the entire water body. The entire affected water body needs to be put at risk to fail the environmental objectives in case a risk criterion is exceeded at a distinct location in a water body.

Results and Discussions

Main hydromorphological alterations that were analyzed are: water abstraction, impoundments/ reservoir effect (interruption of the river continuity by dam construction), hydropeaking, density of irrigation canals and flood protection levees.

Water abstraction. The main source of fresh water is the Prut River. Towns Briceni, Edineț, Cupcini, Glodeni, Ungheni, Leova, Cantemir and Cahul are supplied from the Prut river. The water abstraction decreased by almost 5 times during the last 20 years and now is equal to 27 mil. cub. m. At the same time, the structure of water use over the major sectors remained unchanged (fig. 2). The problem with water abstraction is the high losses of water in the process of transportation (about 3 mil. cub. m per year), which is approximately 15% of total.

An average of 21% of water is used for ***municipal purposes***. The water use has stabilized over the past 4 years at a level of 3.7 mil. cub. m. There are almost 100 water users in the Prut River Basin. The largest water users are the companies providing water supply and sewage services. The most important areas in the structure of water use are Ungheni and Cahul towns.

Annually approximately 4.7 mil. cub. m. of water are used for ***irrigation purposes*** (mean for the 2007-2013 years), which represents 25.2% of total water use and about 1/3 of the water used in agriculture. Although, water abstraction for this purpose was reduced by 75 times in comparison with 1990 and 27 times in comparison with 1995. Northern districts of Moldova (Râşcani, Făleşti, Glodeni and Edineț) are the largest water users for irrigation purposes among the districts, with a share of 53.3%. This area is characterized with the highest density of reservoirs, including the largest reservoir - Costeşti-Stânca.

Water abstraction for industrial needs, just as for the other sectors of economy, significantly decreased in the period from 1990 to 2013 (over 10 times). Over the last 13 years this level decreased by more than 1 mil. cub. m and reached 1.1 mil. cub. m in 2013. The largest user are the regions with large manufacturing outfit. Two sugar factories (in Glodeni and Făleşti) consume 728 thousand cub. m of water per year, which is 45.2% of the total amount of water from the basin used for industrial purposes. Wine industry in Nisporeni, Cantemir and Cahul, baking industry (in Cahul and Ungheni), dairy industry (in Făleşti and Rîşcani), breweries (Cahul), light industry (in Ungheni, Cahul and Făleşti), etc. are among the other major water consumers. The highest water abstractions from the Prut River are recorded in the most populated districts and, respectively, the most industrialized – Edinet, Ungheni and Cahul.

One of the main problems consists in unauthorized abstractions of water from small and medium sized rivers, because this phenomenon exists (but there is no official information about it) and in dry periods it can create unsatisfactory conditions for rivers state, all RWBs were attributed to category of *possibly at risk*.

Reservoirs and flow regulation. Artificial water accumulations have been created to meet different economic needs (fisheries, irrigation, power generation, recreation, etc.), as well as to regulate river flow and control floods. They are divided in two conventional categories: ponds (volume less than 1 mil. cub. m) and reservoirs (volume over 1 mil. cub. m). Ponds and reservoirs in a big number were constructed in the small rivers floodplain and modify the hydrological regime of the RWBs. Number of ponds is about 1300. 46 reservoirs are in the Prut basin, with combined (projected) volume of 825,52 mil. cub. m. Estimations show that, during their operation period, due to siltation, the combined volume of reservoirs has decreased by an average of 0,50% per year, and the volume of Costesti-Stinca Reservoir – by 0,58% per year, making its effective volume in 2011 approximately 594,4 mil. cub. m. Reservoirs and ponds have unequal spatial distribution. Total water surface counts from 1.5–4% of the total area of RWBs basins in the north to 0.5–1.5% in the south.

Within the Prut River Basin, there is a single Hydraulic Power Plant (HPP) Costeşti-Stânca. This allows irrigating around 140,000 hectare of bottomland area, which is around 70,000 hectare on the territory of Moldova. Having the total volume of 678 mil. cub. m, Stânca-Costeşti reservoir allows to reduce the risk of flooding (with probability 1%, and outflow of 2940 to 700 cubic meters per second) so that 34 settlements with over a hundred thousand people that are located downstream could be protected against periodic floods. Hydropeaking effect, except flood events, is not characteristic for Costesti-Stinca HPP. From this point of view, the hydrotechnical complex presents low pressure on hydrological regime.

In comparison with the Prut River, controlled only by one reservoir, the flow of its tributaries is regulated by cascade of reservoirs. The most impounded RWBs are situated in the Middle Prut Plain, in the Camenca River Basin. Over 300 reservoirs are situated on small rivers, their impact on flow distribution can-

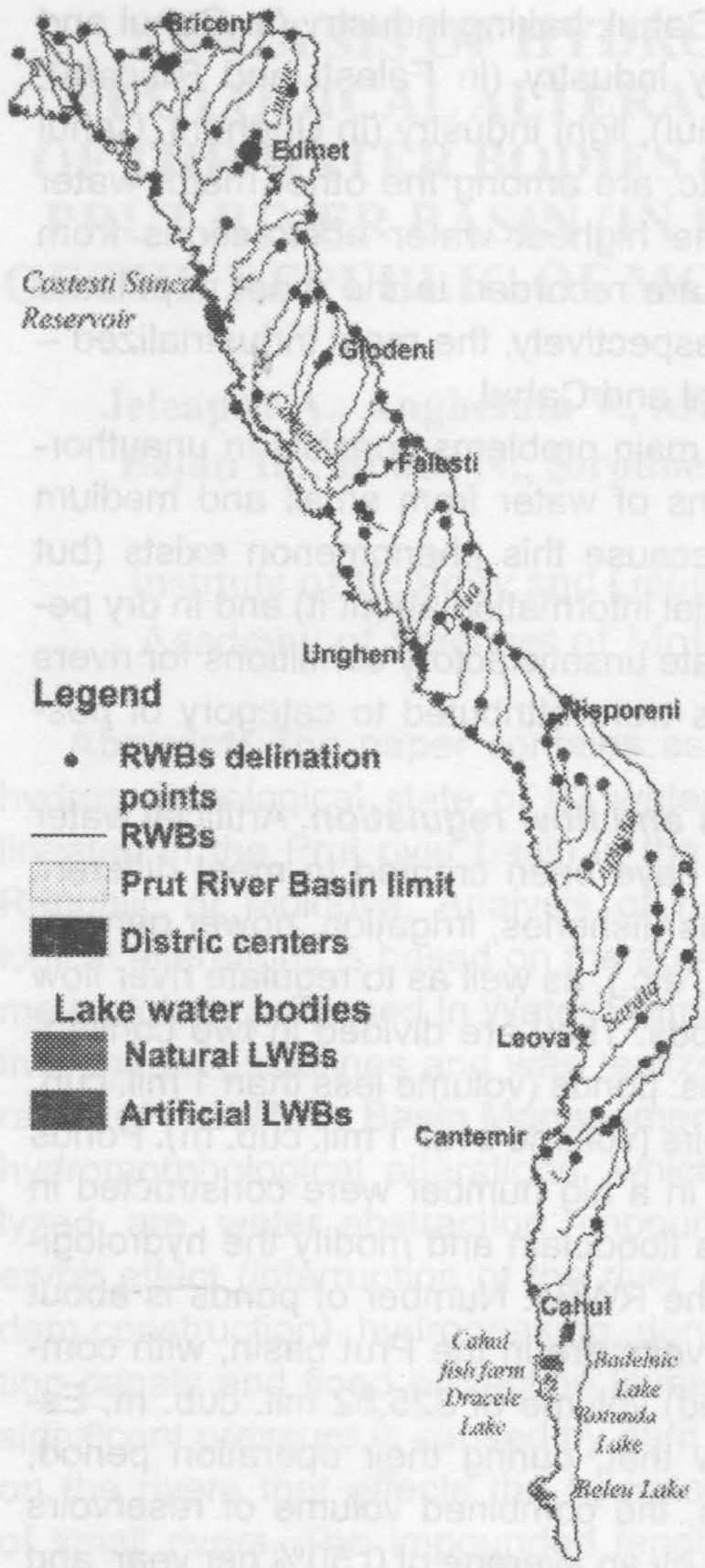

Figure 1. RWB of the Prut River Basin in the limits of Moldova

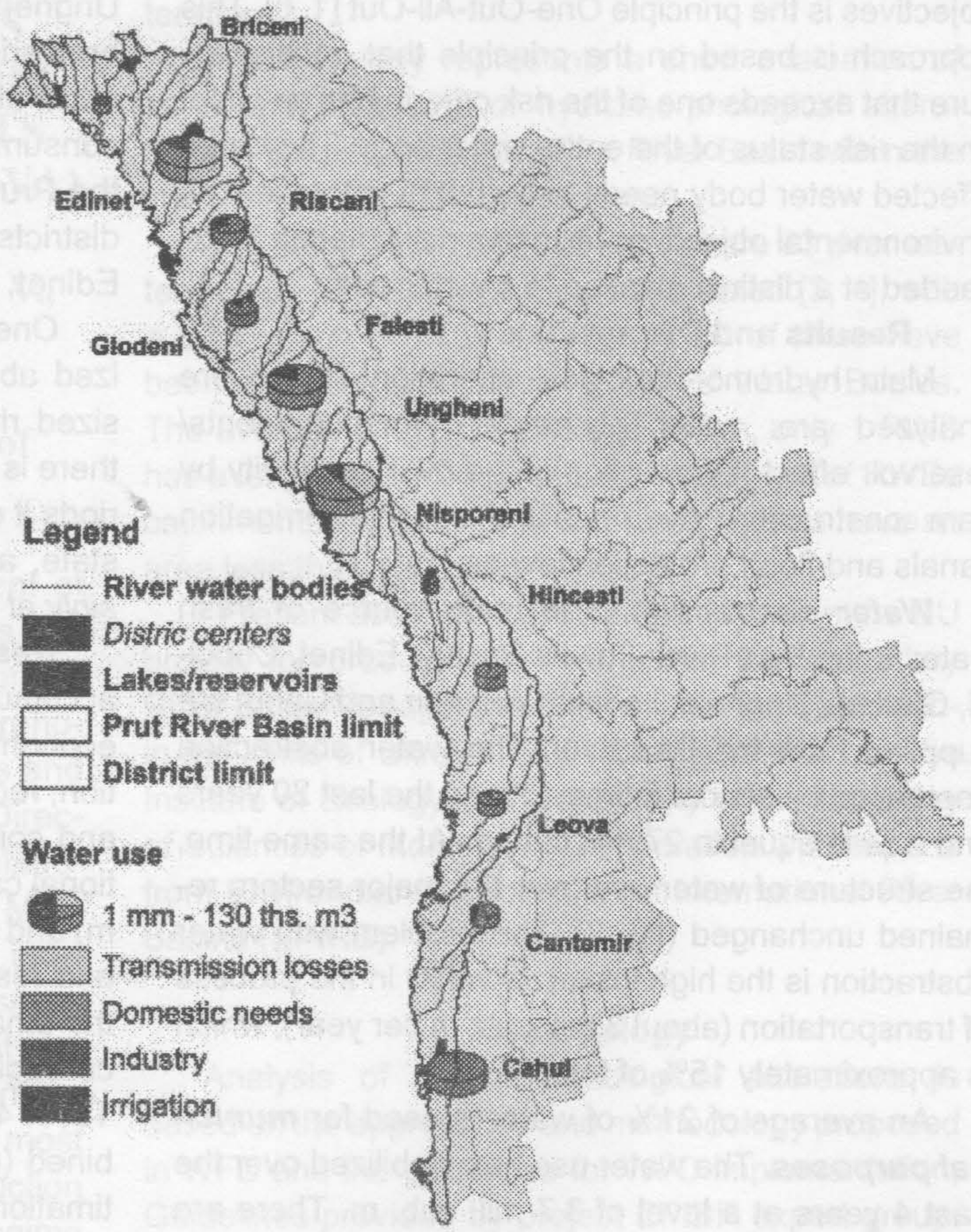

Figure 2. Water use, 2013

Table 1. RWBs under impact of impoundment/reservoir effect

Risk type	Not at risk / No reservoirs	Possibly at risk	At risk
Number of RWBs	11 / 20	30	22
Percentage, %	13/24	36	27
Total lengths, km	296 / 755	657	444
Percentage, %	14/35	31	21

not be evaluated because of lack of monitoring data.

The method of identification of water bodies at risk of failing the environmental objectives in accordance with impoundments/reservoir effect consists of estimation of share of impounded length of the RWB from its total length. If the share is less 10% then the RWBs are considered not at risk, in case of 10-30% the RWBs are possibly at risk and if the share is over 30 then the RWBs are at risk of failing the environmental objectives of WFD. Impoundments/reservoir effect is a widespread pressure. 20 water bodies are not impacted by reservoirs at all. Only 11 are low influenced by reservoirs and are included in group of water bodies *not at risk*. They are represented by the Prut river (there is only one reservoir - Costeşti-Stinca) and some of its tributaries, which are located in the plateau areas, where the construction of reservoirs is more problematic due to specific landscape. 30 water bodies are *possibly at risk* (ex. Ciuhur, Sarata, etc.), and 22 water bodies are *at risk*. Water bodies at risk are predominantly located in the Northern part of pilot basin, most of them being within the limits of the Middle Prut Plain (Caldarusa, Glodeanca, Ustia, Garla Mare, Şoltoaia, etc.) (fig. 3).

Irrigation and drainage canals. The irrigation and drainage system was constructed in the downstream part of the Prut River Basin in 1970-1980. It includes a number of drainage and collecting canals and over 20 drainage pumping stations. In recent years, Moldova has been widely practicing rehabilitation and expansion of irrigation systems that is to be followed by expansion of irrigated fields.

In the Republic of Moldova, 26 water users as-

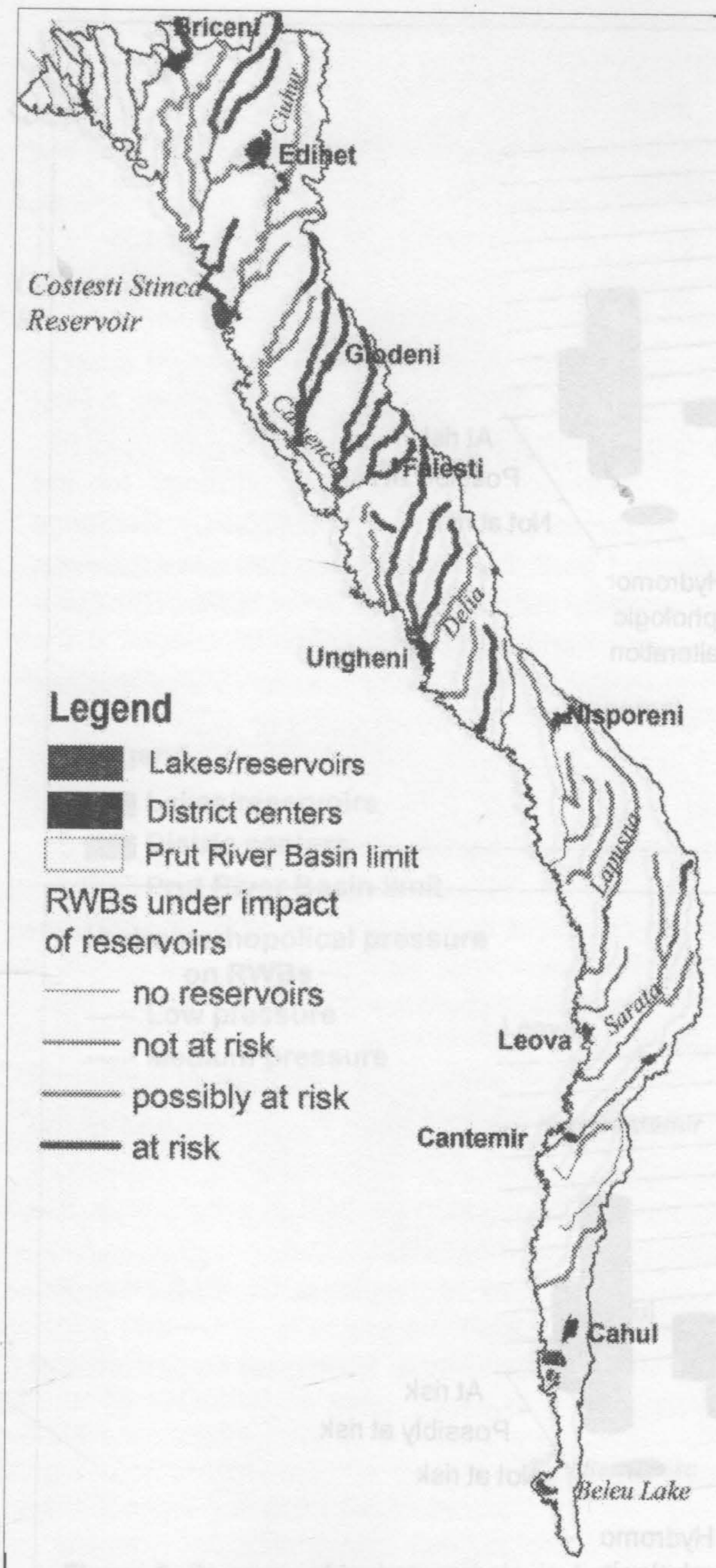

Figure 3. RWBs under impact of reservoirs

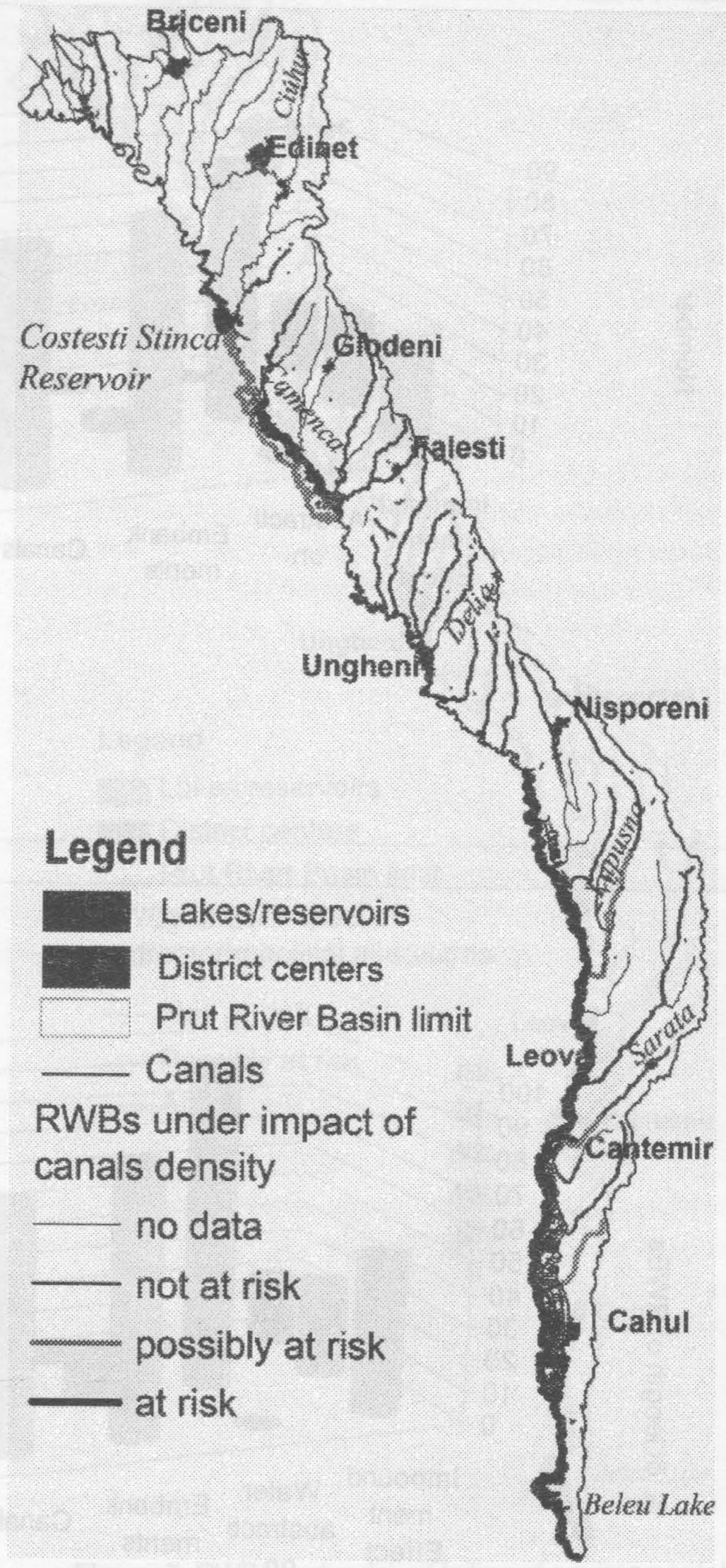

Figure 4. RWBs under impact of canals

Table 2. RWBs under impact of canals density

Risk type	Not at risk / No canals	Possibly at risk	At risk
Number of RWBs	31/42	6	4
Percentage, %	37/51	7	5
Total lengths, km	715/873	173	391
Percentage, %	33/41	8	18

Table 3. RWBs under effect of embankments

Risk type	Not at risk / No dams	Possibly at risk	At risk
Number of RWBs	8/70	4	1
Percentage, %	10/84	5	1
Total lengths, km	307/1472	318	55
Percentage, %	14/68	15	3

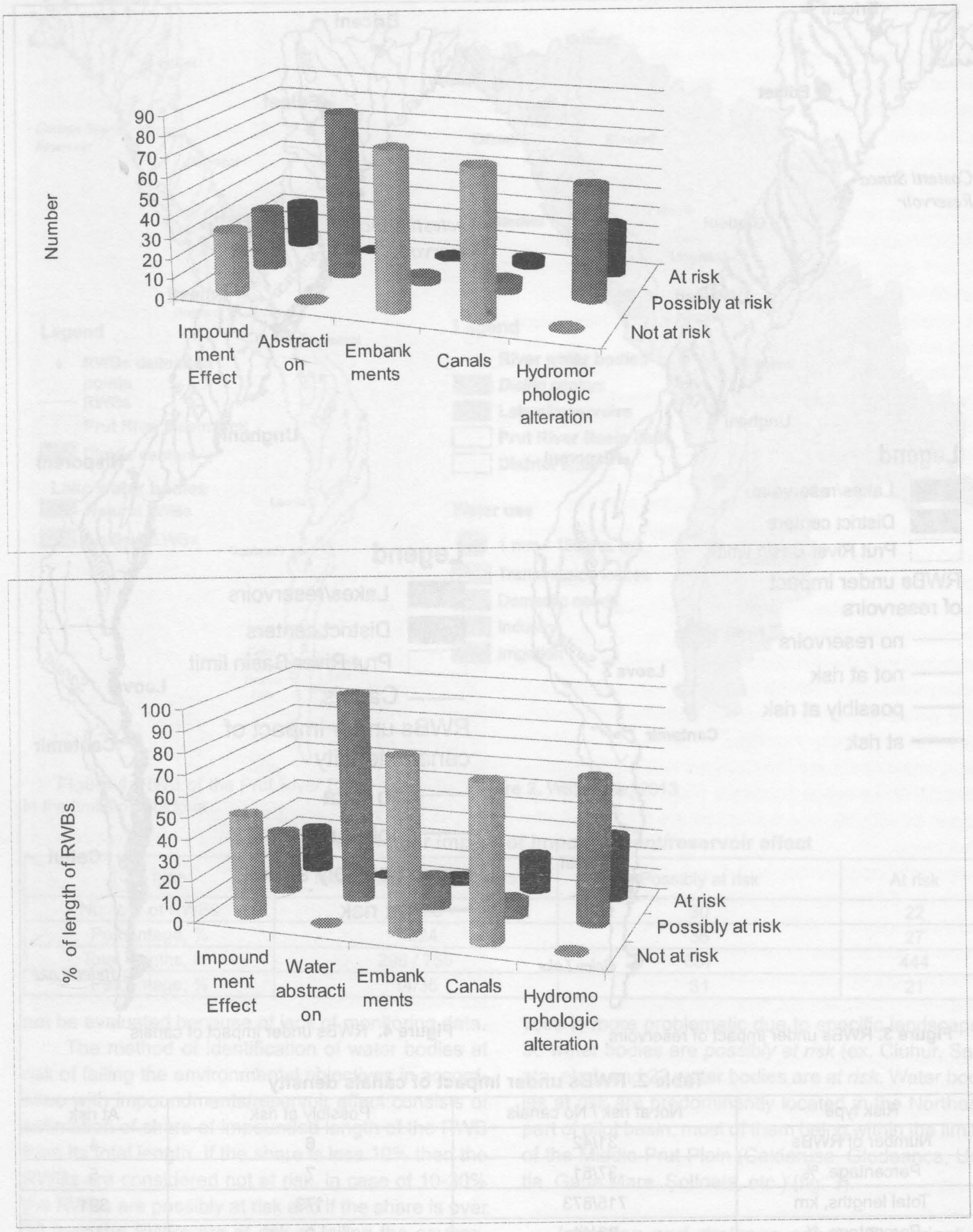

Figure 5. Number and length of water bodies under hydromorphological alteration

sociations were registered to date with only 6 of them located within the Prut basin. A spatial analysis of the registered water users shows their non-uniform areal distribution. 33 irrigation systems exist within the Prut basin with a total area fitted for irrigation of 51481 hectares. The biggest irrigation systems are located in the lowlands, in two regions – The Lower Prut Plain and Camenca River (the Middle Prut Plain), within the limits of Cahul, Cantemir, Leova, Hincesti districts.

The density of irrigation canals depends on the specifics of landscape, having the same spatial distribution as flood protection levees. These areas will increase, due to expansion of irrigated areas projects, so the influence of this factor will increase. Regarding

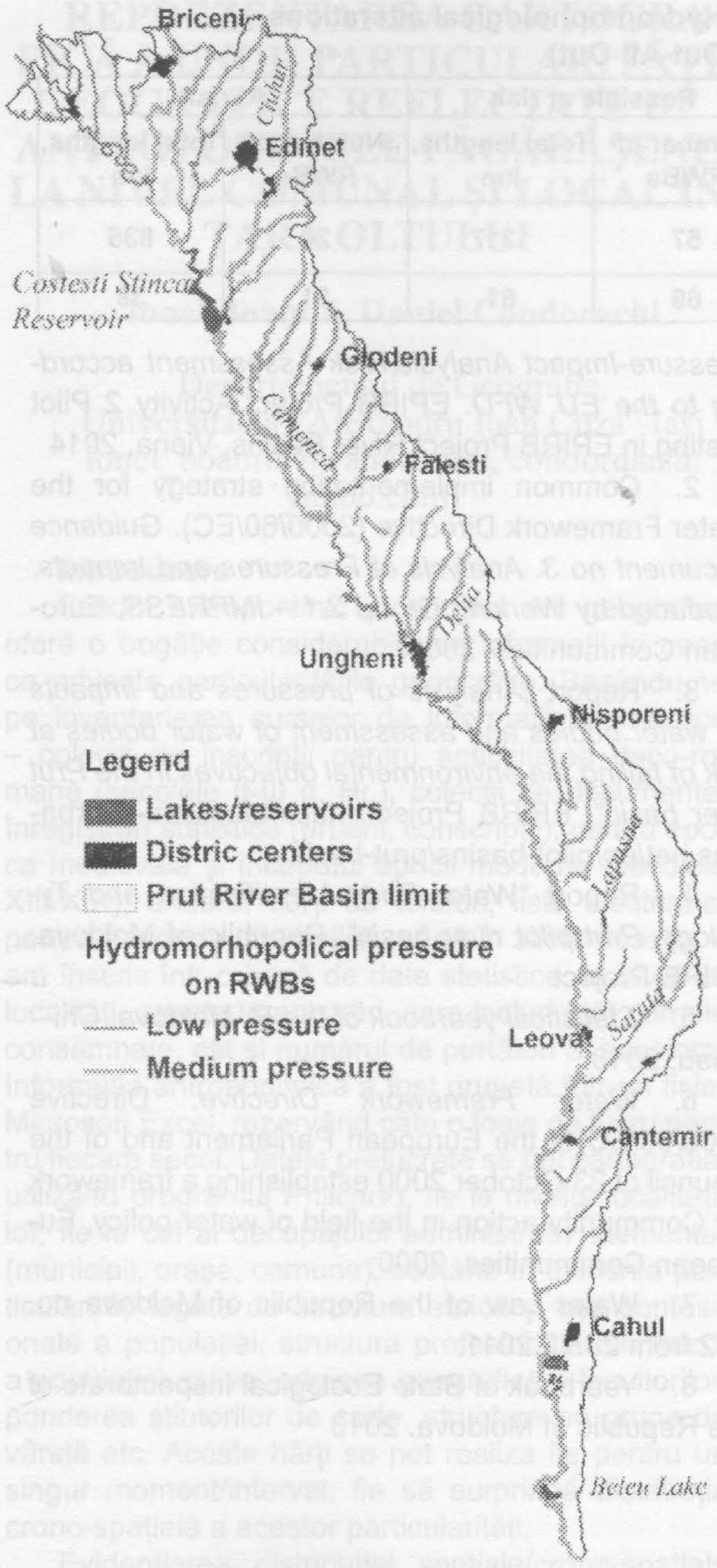

Figure 6. Pressure of hydromorphological alteration on RWBs (Principle: Sum of parameters)

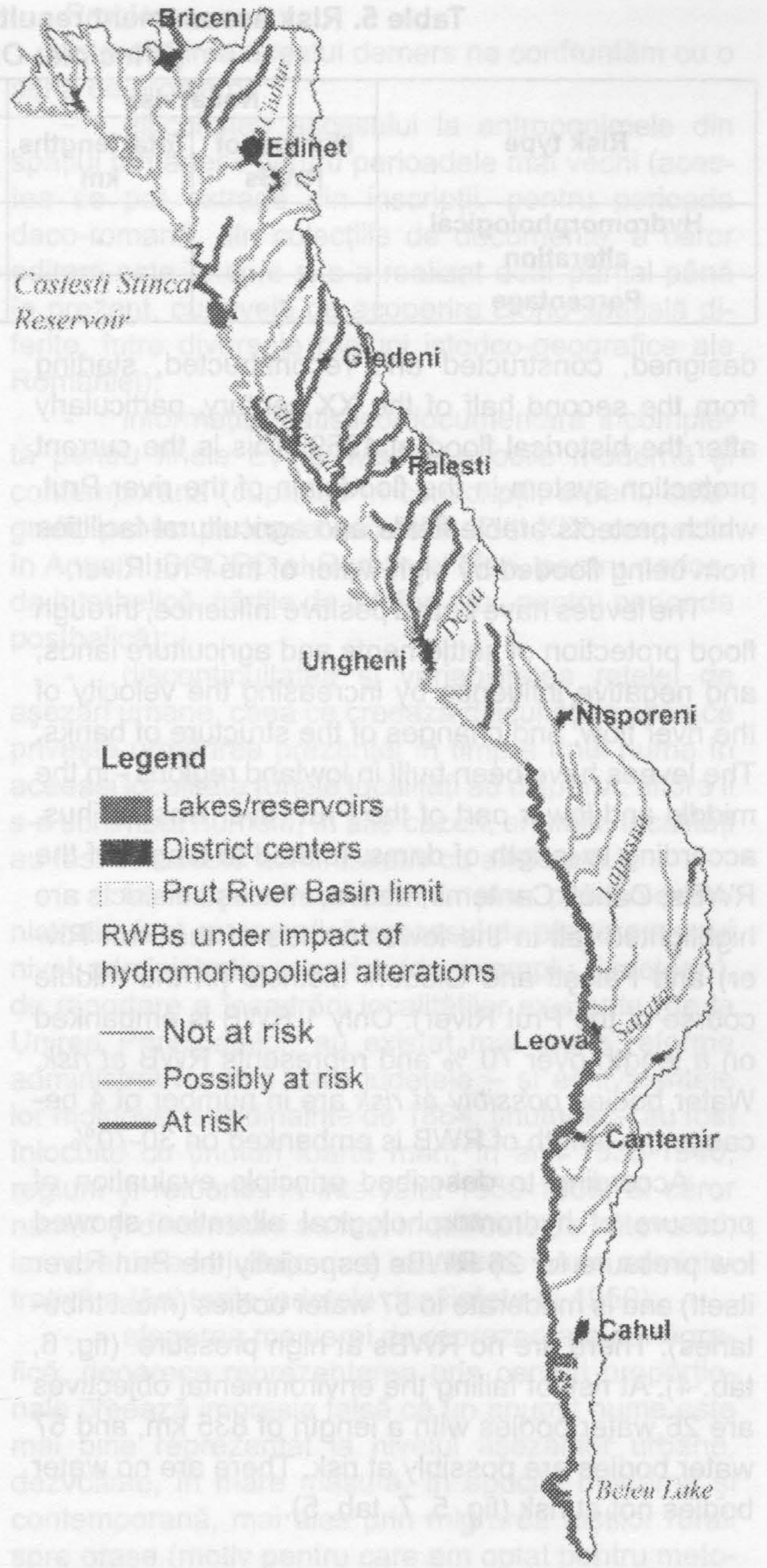

Figure 7. RWBs under risk of failing of environmental objectives based on hydromorphological alteration (Principle: One-out-all-out)

Table 4. Pressure assessment results - Hydromophological alterations (Principle: Sum of parameters)

Pressure	Low pressure		Moderate pressure		High pressure	
	Number of RWBs	Total lengths, km	Number of RWBs	Total lengths, km	Number of RWBs	Total lengths, km
Hydromorphological alteration	26	644	57	1508	-	-
Percentage, %	31	30	69	70		

canals density impact, RWBs were divided in: RWBs not at risk when the canal density is less 0.1 km/km^2, RWBs possibly at risk in case of canal density equal to 0.1-0.3 km/km^2, and RWBs at risk when canal density is over 0.3 km/km^2. At present, total number of water bodies *at risk* is 4 but the total lengths of these water bodies is 391 km (tab. 2).

Flood protection (embankment). National flood protection embankments along the Prut River were

Table 5. Risk assessment results - Hydromophological alterations (Principle: One-Out-All-Out)

Risk type	Not at risk		Possible at risk		At risk	
	Number of RWBs	Total lengths, km	Number of RWBs	Total lengths, km	Number of RWBs	Total lengths, km
Hydromorphological alteration	-	-	57	1317	26	835
Percentage	-	-	69	61	31	39

designed, constructed and reconstructed, starting from the second half of the XX century, particularly after the historical flood of 1969. This is the current protection system in the floodplain of the river Prut, which protects arable fields and agricultural facilities from being flooded by high water of the Prut River.

The levees have both a positive influence, through flood protection of settlements and agriculture lands, and negative influence by increasing the velocity of the river flow, and changes of the structure of banks. The levees have been built in lowland regions - in the middle and lower part of the Prut River Basin. Thus, according to length of dams, related to length of the RWBs, Cahul, Cantemir, Leova, Hînceşti districts are highlighted (all in the lower course of the Prut River) and Făleşti and Glodeni districts (in the middle course of the Prut River). Only 1 RWB is embanked on a length over 70 % and represents RWB *at risk*. Water bodies *possibly at risk* are in number of 4 because the length of RWB is embanked on 30-70%.

According to described principle evaluation of pressure of hydromorphological alteration showed low pressure for 26 RWBs (especially the Prut River itself) and is moderate to 57 water bodies (most tributaries). There are no RWBs at high pressure. (fig. 6, tab. 4). At risk of failing the environmental objectives are 26 water bodies with a length of 835 km, and 57 water bodies are possibly at risk. There are no water bodies not at risk (fig. 5, 7, tab. 5).

Conclusions

The most significant pressures in the Prut pilot basins are the interruption of the river continuity by dam construction. The impounded length of 27% of all water bodies is over 30% and include them to the category of at risk of failing the environmental objectives of Water Framework Directive. Because of lack of data, some hydromorphological alterations could not be good enough evaluated and were only conceptually analyzed. This study will constitute the basis for developing Programme of Measures towards attaining environmental objectives and good water status/potential for all water bodies.

References

1. Birgit Vogel. *Guidance Document addressing hydromorphology and physico-chemistry for a Pressure-Impact Analysis/Risk Assessment according to the EU WFD*. EPIRB Project Activity 2 Pilot Testing in EPIRB Project River Basins. Viena, 2014
2. Common implementation strategy for the Water Framework Directive (2000/60/EC). *Guidance document no 3. Analysis of Pressures and Impacts. Produced by Working Group 2.1 – IMPRESS,* European Communities, 2003;
3. Report „*Analysis of pressures and impacts on water bodies and assessment of water bodies at risk of failing the environmental objectives in the Prut river basin*", EPIRB Project. http://blacksea-riverbasins.net/en/pilot-basins/prut-basin
4. Report "*Water Body Identification and Typology, Prut pilot river basin*", Republic of Moldova, EPIRB Project
5. *Statistical yearbook of the R. Moldova*, Chisinau, 2013
6. *Water Framework Directive*. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. European Communities, 2000;
7. Water Law of the Republic of Moldova no. 272 from 23.12.2011.
8. Yearbook of State Ecological Inspectorate of the Republic of Moldova. 2013