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ON THE ECOLOGICAL STATE OF MOLDOVA RIVER IN THE CORDUN AREA

BY

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Abstract. The research was carried out on the section of the Moldova River where the industrial water catchment of the city of Roman is located. The realization of a catchment construction influenced the morphology of the minor bed of the Moldova River over a length of about 400 m. The river was divided into two arms separated by an island. The research highlighted the morphological differences between the two riverbeds, an aspect that also influenced their ecological condition. Both streams do not provide optimal conditions for the aquatic and riparian habitat in the current stage of operation. The research revealed that the left arm cannot provide good habitat conditions due to the hydraulic characteristics of the catchment. The secondary bed is not regularized and has an uneven water supply. The acrid situation does not allow the achievement of the hydraulic and biological parameters of the habitat's existence.

Keywords: degradation, habitat, river morphology, water catchment.

1. Introduction

The realization of hydrotechnical constructions in the riverbed can cause a significant disturbance of the aquatic habitat and that of the riparian area. A situation of this type is represented by the accomplishment of the water

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withdrawals, which requires the presence of special hydrotechnical constructions in the riverbed. The hydrological parameters are continuously modified and influence the morphological evolution of the riverbed, but also the behavior of the constructions located in the riverbed and in the riverine area. The morphological change of the riverbed causes the formation of river, meandering, river arms, islands, etc., where the aquatic habitat is disturbed and even destroyed (Avram, 2020, Nilsson and Bergren, 2000, Santillán *et al*., 2020).

The catchment area imposes a section gauge calibrated as a section and along the length, with relatively high water depths, high speeds and high flows. Such a riverbed does not present optimal conditions for the protection of the aquatic habitat. Such a situation is presented by the water catchment project located on the banks of the river Moldova in the Cordun area, Neamt County. The execution of the capture required the creation of a secondary arm of the river in which the viable living conditions of the aquatic habitat are not ensured.

On many watercourses and in addition to the riparian area, protected natural sites are located. These sites contain protected flora and fauna components, for which optimal living conditions must be ensured. The degradation of the riverbed also destroys the protected habitat. In this case, the ecological reconstruction of the riverbed must be carried out (Diaconu, 1999, Petts and Calow, 1996).

The purpose of the paper is to present the results of the studies and researches regarding the ecological state of the Moldova river bed and the riparian area in the area of Cordun, Neamț County, affected by the presence of a water catchment.

2. Research material and methods

The studies and researches were carried out on a section of the Moldova River located near the town of Cordun in Neamț County (Fig. 1).

The Moldova River is a left tributary of the Siret River and is 205 km long. The longitudinal profile of the river is balanced and has an average slope of 1% (Ujvari, 1972). In its lower course, the Moldova River is a submontane collector of the Subcarpathian Region, a situation in which the water intakes for large towns (Pașcani, Iași, Roman) and small river towns are located here.

The research material is made up of the area that also includes a section of the Moldova river on which the industrial water catchment of the Roman city is located (Fig. 1). The water catchment is carried out on the river bank and is equipped with a series of constructions made in the riverbed: calibrated riverbed, bottom threshold, energy sink, shore protection, and other. The main research material consists of the regularization works of the river Moldova (steering dams, closing beams, and bottom thresholds) and the works of defence of the left and right banks on the minor riverbed (Luca, 2011). The execution of the capture required the creation of a secondary arm of the river to ensure the transit of the flows during the working period.

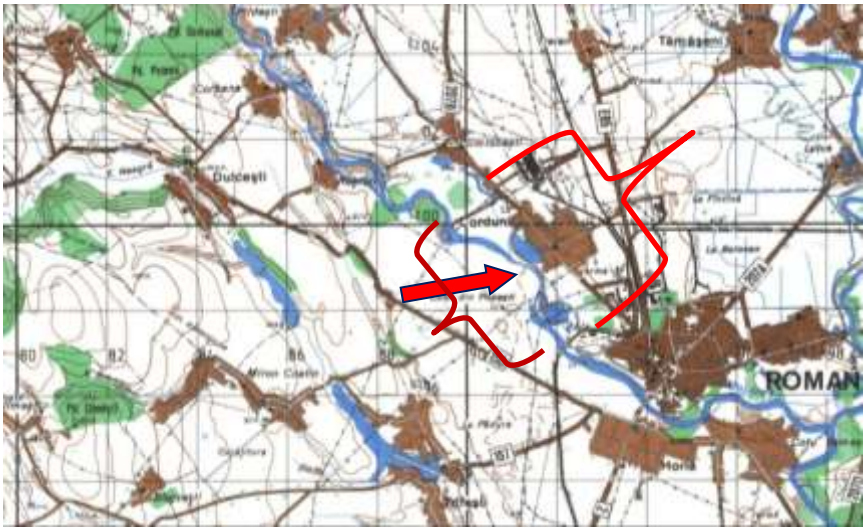

Fig. 1 – The location of the study area on the Moldova River in the area of Cordun, Neamt County.

Theoretical and experimental research was carried out in the following directions:

1. Research of the hydrological and hydraulic parameters of the Moldova River in the study area.

2. To investigate the behaviour in time of the habitat protection mode on the main riverbed of the Moldova River in the water catchment area.

3. Investigation of the behaviour of the habitat protection mode on the secondary riverbed in the water catchment area in time.

4. Analysis of the ecological reconstruction of the secondary riverbed in order to ensure the optimum living conditions of the aquatic and riparian habitat.

The Moldova River presents a meandering route in the study area. The river sector considered in the analysis has an orientation N W - S E.

On the investigated river section, the average and maximum flows taken from the Tupilati and Roman Hydrometric Stations were analyzed. The analysis of hydrological data revealed a relatively high frequency of floods in the last 20 years (Luca *et al*., 2019).

The analysis of the structural and functional status of the riverbeds on the two arms was performed by direct inspection, visualization of the degradation forms, measurement of the geometric and hydraulic parameters, analysis of the aquatic and riparian habitat, the realization of photo and video surveys, and other (Luca, 2011; Luca *et al*., 2018; Luca *et al*., 2019; Sion *et al*., 2019). The data taken from the field were compared with those existing in the technical documentation, or in similar works performed internally and externally.

The data collected through the documentation and those from the field research were processed using the statistical, hydrological and hydraulic calculation programs applicable to the case study.

3. Results and discussions

The paper presents the analysis of the ecological status of the river Moldova in the area of Cordun locality in Neamț County. The studies and researches were carried out on the river Moldova, on the sector of the location of water capture for the industrial area of the Roman city. The water catchment influenced the morphology of the minor riverbed of the Moldova River on a length of about 400 m (Luca, 2011). The construction of the capture construction required the division of the river into two arms by creating an island in the area of Cordun (Fig. 2).

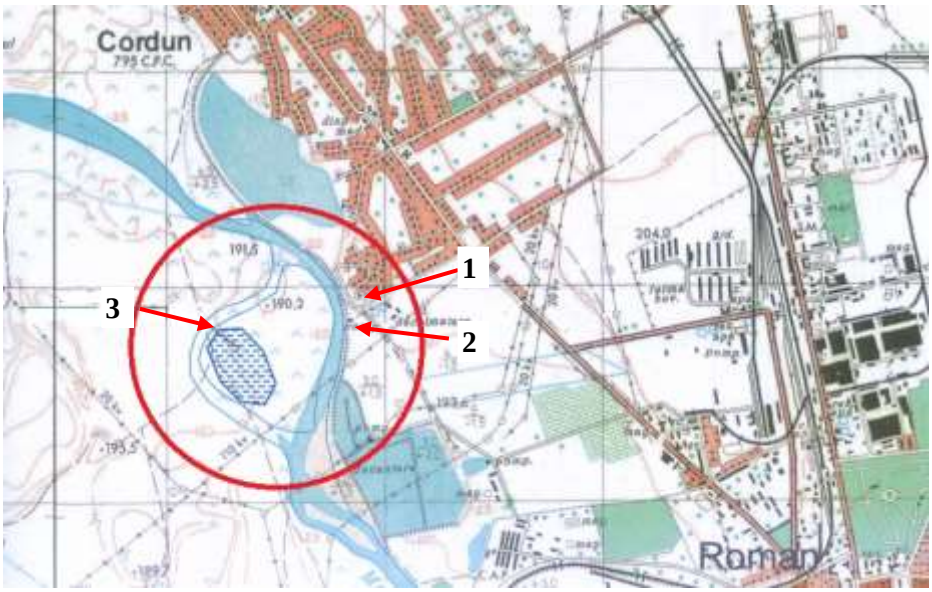

Fig. 2 – The location of the study area in the catchment area on the Moldova River in the Cordun area, Neamț County; 1 – water capture; 2 – main riverbed; 3 – secondary riverbed.

The island in the Cordun area is located at approx. 6.00 km upstream of the confluence of the river Moldova with the Siret River. The surface of the island is 21.0 ha. The industrial water catchment is located on the left arm of the river.

To determine the geometric characteristics of the two arms of the Moldova River bed, topographical measurements were made on the research area (situation plan, transversal and longitudinal profiles) (Luca, 2011). The transversal profile

made downstream of the water catchment highlighted the differentiated geometric shape of the two arms of the Moldova river bed (Fig. 3).

The left arm of the river Moldova in the catchment area has a calibrated section and is rectilinear on a length of 320 m. On this length there are a series of hydrotechnical constructions for regulating the flow of water: bottom threshold, dissipation basin, shore defence. Water flow on the left arm occurs at high speeds (about 1.29 - 2.60 m/s), a situation that does not meet the conditions of protection of the aquatic habitat.

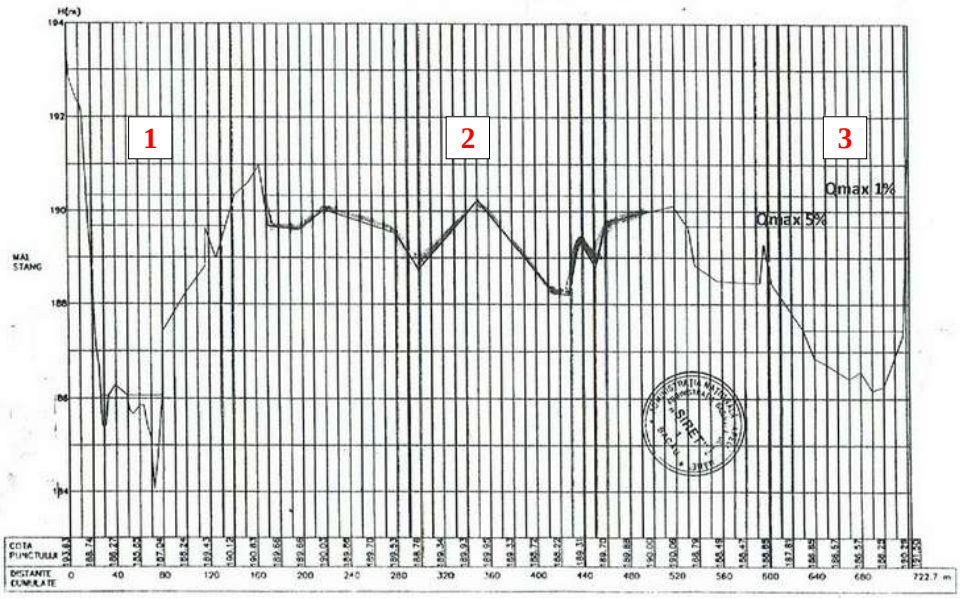

Fig. 3 – Transversal profile in the research area downstream of the catchment: 1 – left arm; 2 – island; 3 – right arm (Luca, 2011; A.B.A. Siret, 2010).

The right arm of the river is fed only at high flows, and the entrance area is provisionally arranged in the form of a spillway. Research has shown that the aquatic environment on the right arm is degraded at the current stage. The morphology of the right arm is continually modified by floods, but also by the average flow rates that occasionally enter due to the degradation of the entrance threshold. The morphological changes are represented by erosion zones and alluvial deposit areas along the right arm length. The water stagnates on some sectors of the right arm and creates an anaerobic environment, which influences the development of the aquatic environment.

Research has shown that the aquatic environment on the right arm is degraded at the current stage. The right arm is affected by morphological changes generated by the floods, which have formed areas of erosion and alluvial deposition. In some areas, water stagnates and creates an anaerobic environment.

The researched area is located in the perimeter of the Natura 2000 site, ROSCI0364 - Moldova River between Tupilati and Roman, being a protected natural area for the conservation of natural habitats, flora and fauna (Luca *et al*., 2019). The research carried out between 2015 and 2019 indicates the adoption of measures to restore the ecological status of the right arm of the Moldova River.

On the river section, researches have been carried out between 2014 - 2019 to analyze the behaviour of the parameters of the riverbed in ensuring the optimal conditions for the development of the aquatic environment.

At the same time, the research analyzed the functioning of the works to regulate the riverbed and the shore defence works in the action of the floods. At the same time, some elements of design of the regularization works were analyzed, as well as other representative materials for the problem studied (Luca *et al*., 2018).

The research used hydrological and hydraulic parameters taken from the meteorological and hydrometric station closest to the study area. Also, a series of hydraulic parameters were calculated for the sections considered in research on both arms of the river Moldova. Some of the hydrological parameters were taken from the Tupilati Hydrometric Station. Extreme rainfall values were recorded at different times of the year. The torrential rainfall is much more present during the last 20 years in the territory of the river basin of the Moldova River (Table 1).

Table 1

Multi-year average precipitation (L/m^2) at Tupilati HS (A.B.A. Siret, 2016)

Month	I	II	III	IV	V	VI	VII
P (L/m^2)	17.9	19.2	24.2	43.6	65.5	83.5	86.1
Month	VIII	IX	X	XI	XII	Annual	
P (L/m^2)	62.9	47.7	28.5	24.3	22.7	526.1	

The high degree of torrential rainfall has generated high values in a very short time. This situation was recorded in the years 1992, 2005, 2006, 2008, 2010, 2016, 2018. The increase of the frequency of precipitations, especially of the torrential ones, with quantitatively significant values, determined the formation of important floods on the Moldova River in the research area. The flood shave negatively influenced the morphological state of the riverbed on the river sectors considered in the research (A.B.A. Siret, 2019; Luca, 2011).

In the last 30 years there have been a series of maximum flows, but also a high frequency of floods in the last 18 years. The maximum flow was recorded in 1991 and had the value of 1402 m^3/s. From the processing of the hydrological data, the flow rates with calculation probabilities (p (%)) used in the design of the constructions located in the river bed resulted (Table 2). The flow values in Table 2 do not include the safety margin according to the current rules.

Table 2
Flows with calculation probability on the Moldova River study sector (A.B.A. Siret 2016)

p (%)	1	2	5	10	20	50
Q_{max} (m^3/s)	1850	1590	1220	960	690.0	52.40
H (mMN)	190.33	190.15	189.70	189.35	188.95	186.62

The study of the technical documentation and the field research highlighted the following characteristic elements of the main riverbed of the Moldova River:

- the main riverbed has a path in the form of a large arc of curved circle to ensure the supply of water capture located on the river bank (Fig. 4 and Fig. 5);

Fig. 4 – View of theriver Moldova River before branching into the area in the Cordun area.

- the left arm of the Moldova river (the main bed) was in an advanced state of degradation, a situation that affects water capture (Fig. 5); as a result, the bed has been recently rehabilitated through the following works: a - reinforced concrete bottom threshold; reinforced concrete energy dissipating pool, and stone and boulder energy dissipator;

a b

Fig. 5 – The current state of the catchment area: a - general view; b - detail regarding the energy dissipation basin at the bottom threshold.

- the left slope of the main riverbed downstream of the catchment has been rehabilitated with a protection from concrete slabs at the top and stone gabions at the bottom on a length of about 120 m (Fig. 5 and Fig. 6); further on, the slope is protected by gabions filled with river stone;

- the slope on the right bank of the main bed has been rehabilitated downstream of the catchment with a protection of river stone gabions;

- the hydraulic characteristics of the water flow in the main stream (high flows and flows, v = 1.30 - 2.60 m/s) do not determine the viable conditions of protection of the aquatic habitat on the section of the catchment area (Fig. 6).

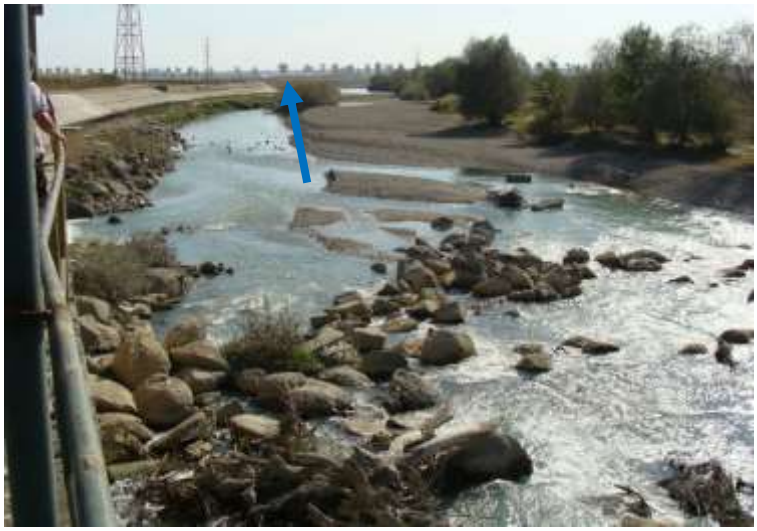

Fig. 6 – The morphological characteristics of the bed on the left arm of the Moldova River in the location of the catchment and downstream of it.

The study of technical documentation and field research revealed the following characteristic elements of the secondary bed (left arm) of the Moldova River:

a b

Fig. 7 – Current status of the secondary riverbed: a - the input sector; b - the central sector.

- the secondary riverbed presents at the entrance a linear sector, then a sector in the form of a circle arc, and the output sector is slightly curved (Fig. 3, Fig. 7 and Fig. 8);

- a concrete spill is made in the entrance section of the secondary riverbed (Fig. 8); the spill is degraded, the operating state is ensured by adding concrete elements and stone blocks after each flood;

- the research showed an influx of water in the secondary riverbed determined by the underground current that crosses the ballast layer between the two rivers;

- the presence of island allows to achieve normal living conditions for the protected species in the riparian area;

Fig. 8 – The branching of the Moldova River bed upstream of the catchment: 1 - the main riverbed; 2 - secondary riverbed; 3 - prague spill; 4 - island.

Fig. 9 – The state of operation at medium flows of the secondary bed in the central sector (1 - island).

- field research has shown that the aquatic habitat in the secondary riverbed is strongly disturbed by the absence of the riverbed development works and the permanent impact of the maximum flow.

Ecological restoration is a process that contributes to the restoration of an ecosystem that has been degraded, damaged or destroyed (Petts and Calow, 1996; Soltesz *et al*., 2012; Șerban, 1999; Wasson *et al*., 1998). This activity is organized in stages, which are carried out at certain time intervals (Avram, 2020).

Fig. 10 – Current status of the secondary riverbed in the output sector;
1 - main riverbed; 2 - secondary riverbed.

The first stage is composed of the operations of investigation of the geometrical and hydraulic characteristics of the secondary bank for obtaining the design data.

The second stage consists in designing the works (hydrotechnical, biological) for the realization of a riverbed that allows the creation of habitat conditions for flora and aquatic fauna. The third stage consists in the transposition into practice of the rehabilitation works of the projected riverbed. In the four stage, a research program is carried out regarding the response of the river to the insurance of environmental factors.

An important role in the research is played by the hydraulic modelling of riverbed degradation phenomena under the influence of natural (floods) and anthropogenic factors (location of constructions in the bed) (Avram, 2020; Chen and Liu, 2017; Rinaldi, 2003, U.S Army, 1993). Hydraulic modelling can predict erosion and silting phenomena and their influence on the ecological state of the riverbed.

4. Conclusions

The secondary riverbeds formed by the rivers do not always achieve favourable conditions for the existence of aquatic and riparian habitat, in which case ecological reconstruction measures of the environment of the river – riparian zone area must be adopted.

The riverbeds on which the catchment constructions are located do not meet favourable coding for the development of the aquatic and riparian habitat, due to the negative influence of the hydraulic parameters existing in the calibrated riverbeds.

On the lower course of the Moldova River there are a series of secondary beds that must be ecologically restored, in order to ensure the conditions for the existence and development of the aquatic and riparian habitat.

The ecological restoration requires extensive field research for the analysis of the degradation mode of the riverbed, the evolution in time of the hydrological and hydraulic parameters, the state of the existing constructions in the riverbed and the shore, the state of the aquatic and riparian habitat, in order to realize the concept of restoration and design of the works. hydrotechnical and biological.

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ASUPRA STĂRII ECOLOGICE A RÂULUI MOLDOVA ÎN ZONA CORDUN

(Rezumat)

Cercetarea s-a efectuat pe tronsonul râului Moldova unde este amplasată captarea de apă industrială a orașului Roman. Realizarea unei construcții de captare a influențat morfologia albiei minore a râului Moldova pe o lungime de circa 400 m. Râul a fost împărțit în două brațe separate printr-un ostrov. Cercetarea a evidențiat diferențierile morfologice dintre cele două albii, aspect ce a influențat și starea ecologică a acestora. Ambele albii nu asigură condiții optime pentru habitatul acvatic și riveran în stadiul actual de funcționare. Cercetarea a evidențiat că brațul stâng nu poate asigura condiții bune pentru habitat din cauza caracteristicilor hidraulice ale captării. Albia secundară nu este regularizată și prezintă o alimentare neuniformă cu apă. Această situație nu permite realizarea parametrilor hidraulici și biologici de existență ai habitatului.