Universitatea „Alexandru Ioan Cuza” Iaşi
Facultatea de Geografie şi Geologie
Departamentul de Geografie

Bd. Carol I. Nr.20A, 700505 – Iaşi, România
Tel.: +4.0232.20.1075, +4.0232.20.1074
Fax: +4.0232.20.1474
http://geography.uaic.ro/

Hydrological study of Middle Prut between Oroftiana and Stanca Downstream. Lake Stanca-Costeşti and its role in the hydrological regime, as well as the role of other environmental components

Doctoral candidate**: Romanescu Ana Maria**

Doctoral tutor,
Prof. Apostol Liviu, PhD

2013 – Iaşi

Abstract

The hydrographical basin of the Prut River is situated in the northeastern extremity of the Danube basin and it shares a border with the hydrographical basins of the rivers Tisa to the northwest (on the territory of Ukraine, Romania and Hungary), Siret to the west (partially on the territory of Ukraine) and Dniester (on the territory of the Republic of Moldova) to the northeast. It occupies the eastern part of Romania. It rises on the slopes of the Eastern Carpathians (Ukraine) and it empties into the Danube near the town of Galați. It has a surface of 27,500 km^2, of which 10967 km^2 on the territory of Romania (around 4.6% of the surface of Romania).

On the Romanian territory, there are 3,450 lakes, of which 2,300 natural lakes and 1,150 artificial lakes: complex reservoirs, ponds, pools, etc. The total surface of the lakes on the territory of Romania is 2,620 km^2. The category of the man-made lakes tends to occupy a significant surface of the lakes on Terra. Currently, 40 man-made lakes measure over 1,000 km^2 (a total of 114,000 km^2) and an overall volume of 1,675 km^3.

The most recent archaeological researches have brought to light vestiges of dams dated around 4,000 years ago. They were built in places with few precipitations, mainly in the Arab countries. Their purpose was to ensure the water supply for settlements and for irrigations. The Marib Dam of Yemen is the best conserved dam and it was constructed in 750 BC; the construction took around 100 years. The earthen dam was 4 m high and it constituted a stone-and-masonry construction. The old dam was resized in 1968; today, it is 38 m high. The lake accumulates a water volume of 398 million m^3.

On the Romanian territory, there are 246 large-sized dams, half of which record heights below 40 m. The highest dam on the territory of Romania is Gura Apelor, on Pârâul Mare, in the Retezat Mountains; it measures 168 m. Other 1,500 dams measure less than 15 m in height, while the reservoirs have volumes under 1 milion m^3. Most large-sized lakes of Moldavia are man-made and only some are natural (Lala, Buhăescu, Roşu, Crucii, Sfânta Ana). In the Romanian Registry of Large Dams, the Stânca-Costești dam is the 49th by the height (out of the 246 dams) and the second by the useful volume of the reservoir (1,290 hm^3, following the Iron Gates I, with 2,100 hm^3).

The strategy of developing and exploiting the rivers is related to certain particularities of the Romanian territory, which must be outlined:

- the great geological and geomorphologic units of Romania were imposed by the "Carpathian crown" in the central part. The main rivers rise in this area and then they drain regions of hills and plains. Hence, the conditions and the morpho-climatic layering of the Carpathians have a crucial influence on the regime of the rivers;

- except for the rivers at the frontier, over 96% of the country's hydrographical network is autochthonous. This made possible a unitary concept of national administration of the river waters;

- almost 97% of the rivers measures less than 50 km in length and only 4 rivers (Siret, Prut, Olt and Mureş) are longer than 500 km. The mean discharge of the rivers in Romania is 1,172 m^3/s, which means an annual volume of 37 million m^3. Because of the territorial repartition and of the regime type, under natural circumstances, the rivers provide only 5-6 million m^3. This is why it has been vital for the national economy to build dam lakes.

In the Romanian Registry of Large Dams (with 246 dams, currently), the Stânca-Costeşti dam is the 49th by the height and the second by the useful volume of the reservoir (1,290 hm^3, following the Iron Gates I, with 2,100 hm^3). The length of the reservoir, at a normal level of retention (NLR 90.80 m), is 70 km, while its maximum length (Nmax 99.50 m) is 90 km. The surface of the reservoir, at a normal level of retention (NLR), is 5,900 ha, while the maximum level (Nmax) reaches 9,200 ha.

The Moldavian Plain, wrongfully categorized among the low-lying landforms, has a monoclinal geological structure, with clayish-sandy formations and mean altitudes of 150 m. The peak altitude reaches 200 m, while the mean landform energy is 70 m. It is improperly called a plain; it would perhaps be better to call it the Jijia-Bahlui Depression or the Moldavian Hills. Concerning the compartmenting of this landform unit, the terms "the Upper Jijia and Başeu Plain" and the "Lower Jijia and Bahlui Plain" were used.

After the construction of Lake Stânca-Costeşti, the floods on the Prut have reduced significantly on the territory of Romania. The territory of the Republic of Moldova is less affected because its bank is higher. The reservoir's attenuation volume of 550 mln.m^3 allows the diminution of a 1% high water from 2,940 to 700 m^3/s; alongside the damming works downstream from the hydrotechnical node, it saves from floods around 100,000 ha of floodplain fields. The irrigations were constructed for around 140,000 ha (70,000 ha for each side). The discharge for water supplying was set to 10-16 m^3/s. The hydroenergy is produced by the two hydroelectric power plants, each with a power unit of 15 MW (discharge Q=2x65 m^3/s; power E=2x65 GWh/year) (the Hydropower Node of Stânca-Costeşti, 2013).

For the study of hydrological risk, the historic maximums recorded on the entire itinerary of the stream are analyzed. The maximums were recorded in the section of Rădăuți Prut, with values of 7,140 m^3/s for discharge and 1,130 cm for level. The danger mark (DM) was reached on 26.07.2008, at 10 PM, when the value recorded 625 cm (+25 cm over the DM and a discharge of 2,090 m^3/s). The danger mark was maintained until 30.07.2008, at 6 PM, when a level of 608 cm was recorded (+8 cm over the DM and a discharge of 1,920 m^3/s). The highest values were recorded on 28.07.2008, between 9 PM and midnight. After two years of analyses, the historic level of 7,140 m^3/s was replaced with the level of 4,240 m^3/s. The first value represented the historic maximum for all the rivers in Romania. The value of 4,240 m^3/s is the second high in the hierarchy of the historic discharges in Romania, after the ones of the Siret River – in the summer of 2005 – of 4,650 m^3/s.

The description of the most important floods on the Prut River underlines that the discharges and the levels record lower values from upstream to downstream. In this case, the situation is reversed because the Stânca-Costeşti reservoir takes over most of the excess water and releases it gradually, depending on the downstream levels. The high-water waves in the upstream dam sector are sharp, with abrupt highs and lows, while the high-water waves in the downstream sector have a flattened upper part, where the descent occurs gradually. The hydrograph of the high waters downstream underlines the obvious control held by the Stânca-Costeşti dam.

This material analyzes the high water discharges in the period July-August, produced on the Prut River, as well as the levels recorded at various hydrological stations. The role played by Lake Stânca-Costeşti is underlined, as well as what could have occurred if the dam had broken. The hydrological risk of the dam breaking appeared when the water volume accumulated upstream became higher than the initial estimate, reaching an insurance of 0.1%. Actually, this immense water volume accumulated behind the dam constitutes the reason of this hydrological analysis.

The floods are provoked by the heavy rains, many of them with values exceeding 50-100 mm/24 hours. The floods of the Prut River – in the summer of 2008 – were provoked by such rains that fell in the upper basin (Ukraine) and in the middle basin (Romania). The precipitation mean – at several stations in the Prut hydrographical basin, on the territory of Romania – indicates values up to 150-200 mm in 40 days (178.0 mm at the Botoşani station or 209.1 mm at the Cotnari station). The precipitations fallen in the interval 21-27.07.2008 in the Botoşani County could not have caused the catastrophic floods of the Rădăuți Prut section. They are ascribed to the precipitations fallen in the Eastern Carpathians of Ukraine, as well as

to unauthorized water discharges within a reservoir placed on the upper Prut stream (unfortunately, this piece of information has not been confirmed officially).

The discharges and the maximum levels on the Prut River were recorded in the sector upstream from Lake Stânca-Costeşti, in the Rădăuți Prut sector: 7,140 m^3/s and 1,130 cm, respectively. The danger mark (DM) at the Rădăuți Prut Station was reached on 26.07.2008, at 10 PM, when the recorded level was 625 cm (+25 cm over the DM and a discharge of 2,090 m^3/s) and it was maintained until 30.07.2008, at 6 PM, when the level dropped to 608 cm (+8 cm over the DM and a discharge of 1,920 m^3/s). The highest values were recorded on 28.07.2008, between 9 PM and midnight. At the same time, the danger mark was also reached at the Oroftiana station, while at the Stânca-downstream station, the flood mark (FM) was reached.

The levels reached maximum values at the Rădăuți Prut station, meaning 1,130 cm, on 28.07.2008, between 9 PM and midnight, that is +530 cm over the danger mark (DM). This level dropped significantly, to only 512 cm, at the Stânca-downstream station, on 31.07.2008, between 7 AM and 3 PM, that is +137 cm over the danger mark (DM). Until the Prut empties into the Danube, the levels ranged between 500 and 650 cm, which means 10, 20 cm over the danger mark (DM). The mitigating role of the Stânca-Costeşti reservoir is apparent, but the maintenance of the high levels for 20-30 days is determined by the accumulation of an immense water volume in the lake and by its distribution toward downstream for a far too long period. Precisely the slow water discharge could lead to the damaging of the dam. The hydrostatic pressure on the dam was manifested for far too long, mostly considering that the dam had never been tested on such a level.

The subsequent floods downstream from the Stânca-Costeşti reservoir were mainly due to the water excess discharged from the lake, and less to the water from precipitations. The attention mark (AM) at the Rădăuți Prut station was maintained only until 31.07.2008, at 8 PM. After this date, the maximum amounts of precipitations fallen in the Prut hydrographical basin could not have favoured floods such as those occurring on this river. Hence, the floods on the Prut, downstream from the Stânca-Costeşti reservoir, caused by a poor management, can be considered accidental, but also under control.

Toward the end of the heavy rains (31.07.2008), the level of Lake Stânca-Costeşti reached the maximum values of 98.27 cm, cu +7 cm FIII, with maximum input discharges of 1,290 m^3/s (31.07.2008, 3-6 AM). The mitigating role of Lake Stânca-Costeşti was decisive in preventing the high water wave from manifesting violently downstream from the dam, too. The entire water volume that ran off on the upper basin was captured and held within the lake. Downstream from the dam, the evacuation discharge of the lake determined, as expected, an increase in the discharges and levels at the Stânca-downstream station. Down to the point where the Prut empties into the Danube, the levels did not exceed the flood mark until the month of August.

The high water wave, downstream from the Stânca-downstream station, propagated slowly because of the mild slope and of the control exerted by the dam. At the downstream stations, it arrived rather late and at the Oancea station – the last on the Prut path – it ended on 29.08.2008. To the values of the stations situated downstream from the Stânca-downstream stations, additional discharges from the tributaries within the lower basins were added. Nonetheless, the floods within the middle and lower basins were not catastrophic. After the construction of Lake Stânca-Costeşti, the floods on the Prut have reduced significantly on the territory of Romania.

The seasonal campaign of 2008 enabled water samplings, necessary to conduct a complex analysis on the quality of water within the Stânca-Costeşti reservoir. From a qualitative perspective, five quality classes were used. The measurements were taken by using the HACH Multi-parameter meter (for the physico-chemical parameters) and by using the

nets in order to get samplings for analyzing the phytoplankton. The trophicity of lake waters is characterized by the physico-chemical and biological indicators, among which: pH, CCO-Cr, CC=-Mn, CBO_5, total mineral nitrogen, total phosphorous, temperature, dissolved oxygen, transparency, nutrients, structure of aquatic biota (value of phytoplankton biomass, V90% value of plankton biomass, coliform bacteria), etc.

From an ecologic perspective, the waters of the Stânca-Costeşti reservoir belong to the second quality class. The chemical state of the waters within the Stânca-Costeşti reservoir was determined in relation to the concentration of hazardous and priority hazardous substances: dissolved fraction of the heavy metals and organic micro-pollutants. The determinations concerned the monitoring sections and they were made depending on the following substances:

-metals and compounds: Cu, Zn, Pb, Ni;

-organic micro-pollutants: lindane, endrin, aldrin, dieldrin, pp-DDT, isodrin, alachlor, anthracene, naphtalene, fluoranthene, phenanthrene, benz(a)anthracene, benz(b) fluoranthene, benz(k) fluoranthene, benzo(a)pyrene, benzo(g,h,i)perylene, indeno(1,2,3)pyrene, chrysene, simazine, atrazine, trifluralin, 1,2,4 trichlorobenzene, 1,2,3 trichlorobenzene, pentachlorobenzene, hexachlorobenzene, benzene, toulene;

-o-xylene, (m+p) xylene, ethylbenzene.

As for the physico-chemical indicators, exceeding values are recorded only for lead (Pb) and copper (Cu) – the dissolved fraction. Unfortunately, the standards of quality for the "water" investigation environment (Order No. 161/2006) concerning dissolved metals – especially copper (1.3 µg/l), chrome (2.5 µg/l), niches (2.1 µg/l), and lead (1.7 µg/l) – are far too restrictive. In this case, the value of the natural background in the Prut region – which features excess values for copper, chrome, nickel, and lead – has not been taken into account.

The bathymetric measurements underline a lacustrine cuvette with increasing depths in the downstream sector. The maximum depth is 29.2 m and it is recorded near the dam. The most significant depths are near the abrupt, rocky banks. The least significant depths are in the upstream sector and at the mouths of the main tributaries. In the lake per se, the depths range between 10 and 15 m. The Moldovian bank is abrupt, and the channel is in its vicinity. The Romanian bank is less defined and it gradually prolongs toward the centre of the lacustrine cuvette.

In order to underline the degree of clogging, 17 profiles– longitudinally and in cross-section – linking the two banks, Moldovian and Romanian, were executed. The profiles were chosen to emphasize on the way in which the material was deposited or on the erosion at the bottom of the cuvette. The main targets were the confluence sectors, where the alluvia deposit is more significant. The high clogging in the upstream sector is due to the reduced depths of the lake in this area and to the rapid depositing of the coarse materials transported by the river. The downstream sector also comprises erosion areas, due to the circular currents induced by the flow of the tributaries and by the local obstacles. At the level of the dam, circular currents – with the role of scouring the alluvia – are formed. Emptying the bottom ensures a rapid elimination of the sediments and it determines a low degree of clogging.

This study underlines the positive role of the Hydropower Node of Stânca-Costeşti, mostly regarding flood attenuation. As novelty in the field (mostly in the Romanian one), the following issues are worth mentioning:

-Short history of dams and reservoirs construction;

-Romania's hydropower strategy and typology of dams;

-The manner of exploiting reservoirs;

-The issue of hydrological risk in the Prut hydrological basin. Case study for the Stânca-Costeşti reservoir;

-The Stânca-Costeşti reservoir and the main geographic characteristics;

-The hydrological regime of the Prut River upstream and downstream from the Stânca-Costeşti reservoir;

-The case study on the hydrological risk – the floods on the Prut and in Lake Stânca–Costeşti in 2008;

-Lake Stânca-Costeşti and its role in the attenuation of the floods on Prut;

-Water quality and management of the Stânca-Costeşti reservoir (Romania – the Republic of Moldova),

-The morphobathymetric characteristics and the clogging rate of the Stânca-Costeşti lacustrine cuvette.

It is the first geographic monograph of this type and it follows the changes occurred in the lacustrine cuvette, as well as the sectors upstream and downstream from the reservoir. The entire activity is strictly monitored because the Hydropower Node of Stânca-Costeşti is administered by two States, with equal rights: Romania and the Republic of Moldova.