Lakes, reservoirs and ponds, vol. **1-2**: 90-98, December 2008

THE WATER BALANCE OF LAKE LEŞU (ROMANIA)

Csaba HORVÁTH
Romanian Academy-Cluj Branch, Geography Department
Cluj-Napoca, Romania
hcs1000@yahoo.com

Abstract
Lake Leşu is one of the reservoirs that form the hidrotechnical complex Drăgan-Iad in the upper basin of the Crişul Repede River. The water balance of the lake is closely linked, to the primary functions of the lake. In this paper, we present each of the components that characterize the water balance, to understand which are the most significant ones. We will see how the different components of the water balance equation effect the change of volume in the reservoir. Every component is calculated separately, so precipitation, evaporation, runoff of the basin and the discharge of the dam.
Keywords: lake volume, precipitation, ice, lake water balance

INTRODUCTION

Lake Leşu in the upper basin of Crişului Repede River, is formed behind the Leşu Dam which is part of the "Drăgan-Iad" hydroenergetic scheme. The evaluation of water balance for a reservoir consists in the quantitative estimation, for a moment in time or for a time interval (decade, month, season, one or more years), of all the water balance components which contribute to the increase or decrease of the lake volume. The volume quantitative modification determined by the input and output of water is reflected in the lake level variations, which can have a positive or a negative course. We can distinguish three typical situations of the lake water balance, through the analysis of the inputted (V_1) and outputted (V_2) volumes (Fig. 1).

So the lake water balance is overflowing when the inflow is higher than the outflow ($V_1>V_2$), it is in deficit when the outflow is superior to the inflow ($V_1<V_2$) and it is in balance when the two volume components are equal ($V_1=V_2$).

The components of the lake water balance determine the water balance formula

$$P + V_s + V_i + V_{De} - V_d - E - I = \pm \Delta W \quad \text{(mm), (m}^3\text{)}$$

where, – P = precipitation fallen over the lake surface;

- V_S = runoff from the hydrographic basin;
- Vi = underground runoff;
- V_{De} =derivations from other hydrographic basins;
- V_d =dischargers of the dam;
- E = evaporation of the lake water surface;
- I = infiltrations in and/or below the dam;

ΔW = lake water volume variation in the time period.

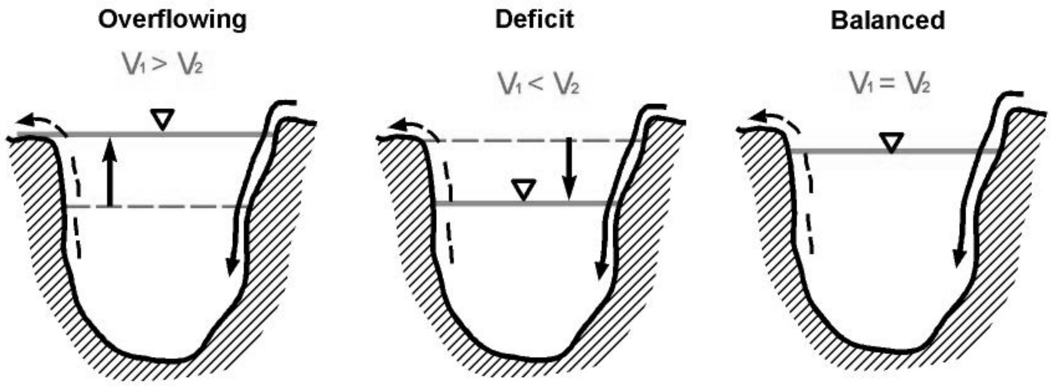

Fig. 1. Lake water balance types (Gâştescu, 1998)**.**

The lake water balance is an integral equation of al the components values which contribute to the input and output of water in the lake volume. The values of these components exceed the simple registration and reflect the interdependences of the physical and geographical factors and their influence over the lake and its surroundings.

1. INFLOW VOLUMES

The positive part of the lake water balance is formed of precipitations and the contributions of surface and underground runoff. In case of the reservoirs, apart of these, the derivation from other hydrographic basins represents an important part.

1. 1. Precipitations

In figure 2, we observe that the values and the variation of the two stations al Lake Leşu are strictly comparable; this is explained by the short distance between the stations and the similar positioning characteristics. In such cases, we could use even the arithmetical method to evaluate the volume of precipitation fallen over the lake surface (1265,6 mm).

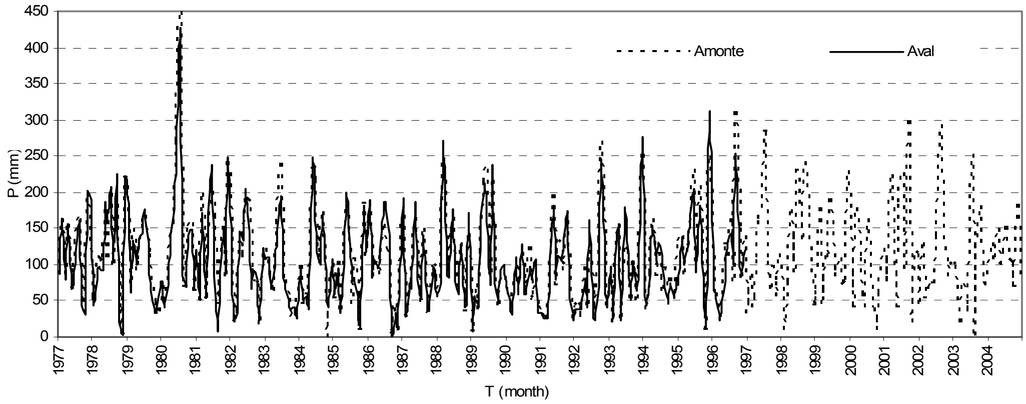

Fig. 2. Precipitations monthly evolution at
Leşu Amonte and Leşu Aval hydrometrical stations (1977-2004)

However, to be sure about the value, we have extracted it from the map of average precipitation in the upper basin of Crişului Repede River whit the help of the „Spatial analyst \ Zonal statistics" extension of the Esri Arc Map\Arc Info software (Fig. 3.).

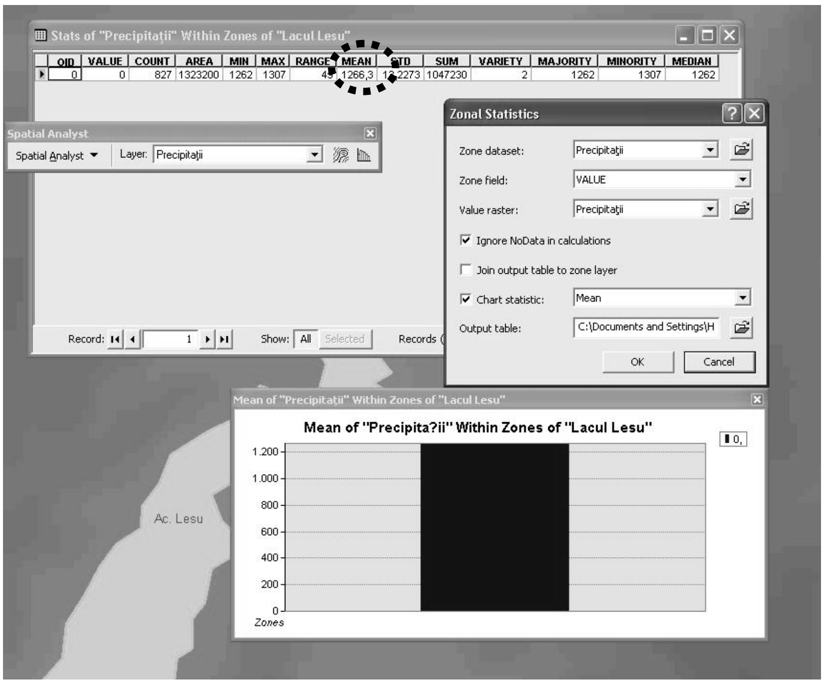

Fig. 3. „Spatial analyst \ Zonal statistics" extension of the Arc Map\Arc Info software used to evaluate the average precipitation fallen over the surface of the lake

Therefore, we can conclude that the multiannual average runoff from precipitation in case of the Leşu reservoir is 0,049 m^3/s, which is the correspondent value of 1266,3 mm runoff. The formula used to transform the values:

$$Q_P = \frac{P \cdot A}{T} \cdot 10 = \frac{1266{,}3 \cdot 120}{3{,}1536E+11} \cdot 10 = 0{,}049 \left[m^3 / s \right]$$

where: P - precipitations in mm; A -lake surface in ha; T - number of seconds in a year.

This represents an yearly average volume of 1518721,3 m^3/year.

In the pluviometric regime, there are two maximums, one in June -July, and another one in winter, in December (Fig. 4). The minimums are characteristic at the end of winter in February and there is another one in autumn, in October.

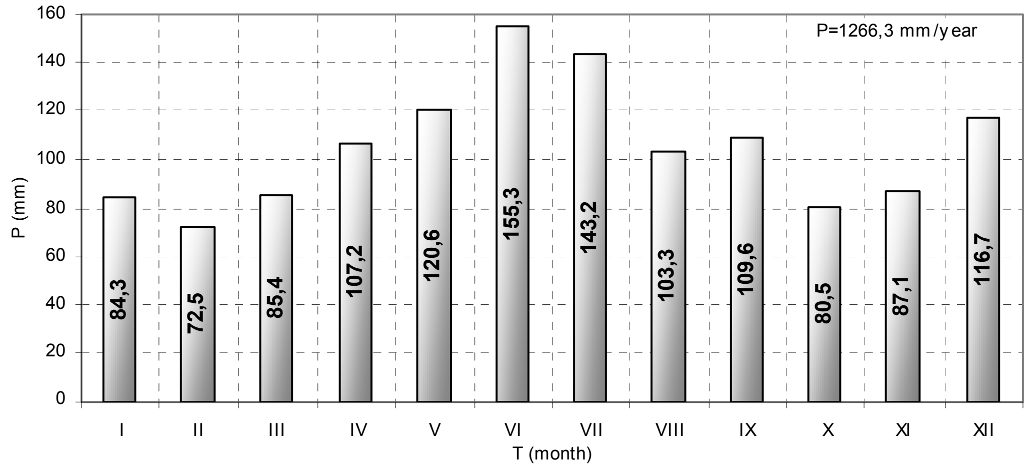

Fig. 4. Repartition of average monthly precipitation (1977-2004)

1. 2. Surface runoff

In the case of the lake balance, it is very important to differentiate the organized runoff in riverbeds and the areal runoff from the lake basin slopes. This is a very complex natural process, which is influenced or even conditioned by a multitude of geographic factors, among which there are strong relations of interdependence and inter-conditioning (Sorocovchi, 2002).

At Lake Leşu the problem is simplified, because there is a hydrological station upstream the lake, and by reconstituting the natural runoff, the volume from the inflow can be calculated relatively easy. With the values from the upstream station and the values from the reconstitution of the dam discharge, we can easily calculate the areal runoff in the lake basin. In this manner, we can calculate the runoff from the interbasinal areas, which are not surveyed by hydrometrical stations.

We mention that the precipitations fallen over the surface of the lake are not considered separately, because they are incorporated in the discharged volumes of the dam.

From evaluating the overall areal runoff for the Iada River basin upstream the reservoir, we calculated that the lake interbasinal runoff is 0,89 m^3/s, which represents 40% of the whole Leşu Amonte station upstream runoff.

The runoff maxima is linked to the volumes retained in winter in form of solid precipitations, the highest values are measured in April-May (Fig. 5.)

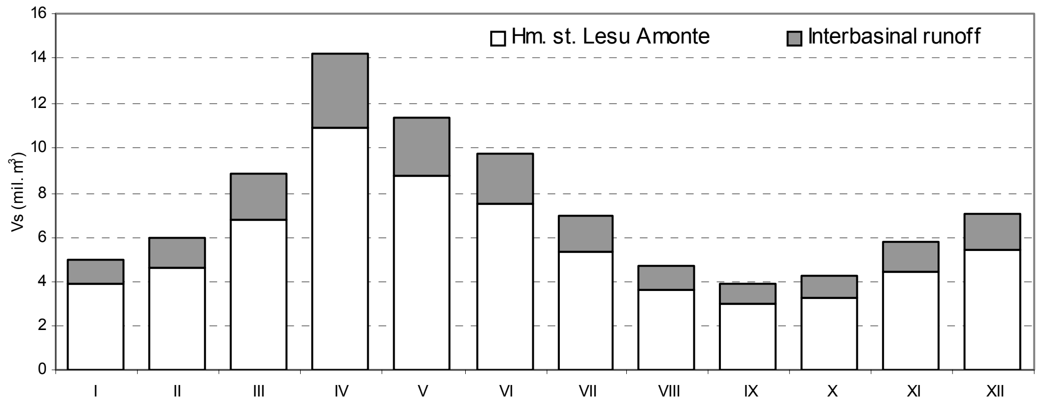

Fig. 5. Monthly average inflow data at Lake Leşu

2. OUTFLOW VOLUMES

The outflow volumes represent the negative part of the lake balance, the volumes lost by the lake. In the studied case the outflow is made by the dam discharges, because the parameters describing them are well known, in this way the water volume can be exactly calculated.

The lake surface evaporated water volume is normally measured directly on the lake in the evaporation pan. Because, there are no measurements on the lake, we had to rely on the correlation between the altitude and the evaporation of other lakes in the area, which are equipped with pans.

2. 1. Dam discharges

These are the most important parts of the hydroenergetical scheme, their characteristics being defined even before starting the construction of the dam.

In case of Lake Leşu at full volume, the bottom discharge has a runoff capability of 37 m^3/s. Its construction allows its use as an adduction for the hydroenergetical power station and as a supply for the necessary volumes for the downstream population/consumers.

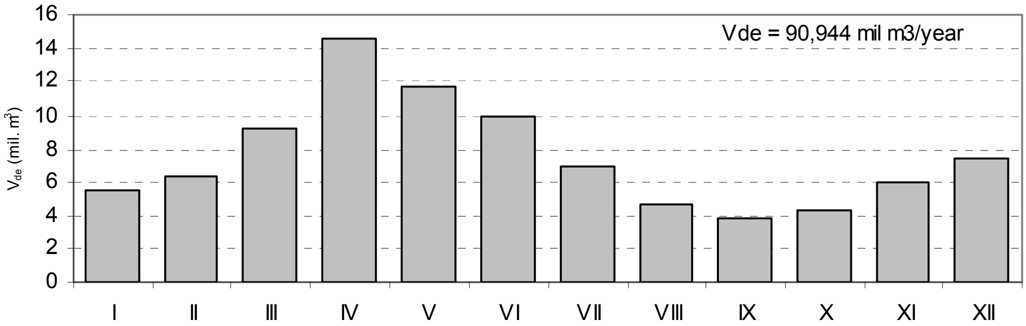

Fig. 6. Monthly average discharge volumes at Dam Leşu

The surface discharger generates an important attenuation of flood waves in the lake. At a runoff equivalent to the calculated 0,1% assurance, equal to 290 m^3/s, after attenuation the downstream discharged runoff is reduced to 192 m^3/s.

In the studied case, we have derivations to other river basins (Lake Cârligatele retention for the Drăgan River basin), but because this is upstream the river the lake balance equation is simplified:

If, $V_a = V_S - V_{De}$

$$P + V_a - V_d - E = \pm \Delta W$$

where, P – precipitations; V_a – inflow; V_d – outflow; E – evaporation; ±ΔW – variation of the lake volume in time.

2. 2. Lake surface evaporation and the infiltrations

The evaporation is one of the fundamental components of the water cycle and the precision of its estimation is essential for calculating the lake balance. It is very difficult to determine the best method to estimate the volume of evaporation. In absence of direct measured data on the lake, we have chosen to evaluate the corresponding volume from the nearby lakes in the area, trying to establish a correlation between the altitudes of the lakes and their average yearly evaporation.

Using the data from the lakes with similar characteristics on the Someşul Mic River, in Câmpia de Vest and some general values determined by Ujvári I. and Gâştescu P., (1958) or Simona, Rusu (2004) with the help of software „Curve Expert 1,3" we worked out the following equation:

$$y = \frac{1}{a + b x^c}$$

where, a (- 0.064736384), b (0.063698531), c (0.0073570438) constants generated by the software „Curve Expert 1,3"; y - evaporation; x - the digital elevation model.

With the help of this correlation, we have calculated the evaporation at different altitudes and extracted the values for the studied lake from the evaporation map created with the help of the Esri ArcGis software group. We have also estimated the monthly values altitude and average yearly evaporation data (Ujvári; Gâştescu,1958) (Fig 7.).

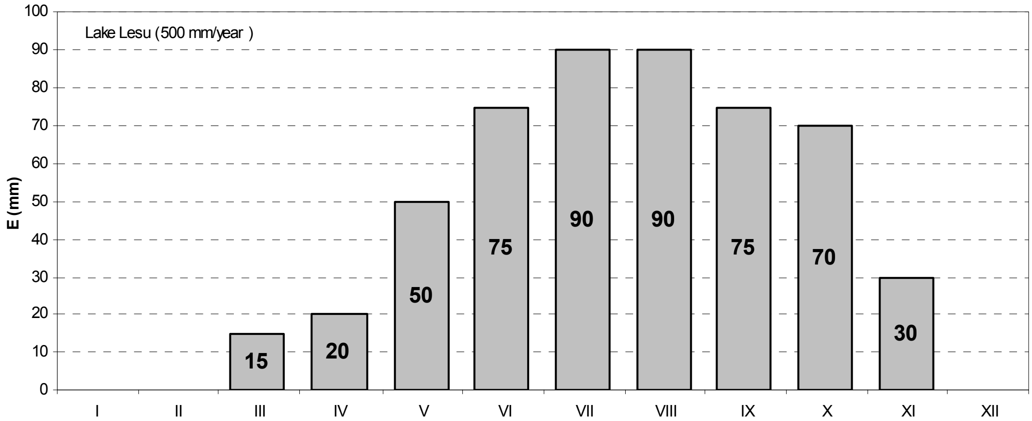

Fig. 7. Monthly average surface evaporation values al Lake Leşu

The underground runoff or the infiltrations could be estimated from the balance equation, if all the other components were known. In addition, by simplifying the equation, we can consider the input and output of the infiltration in the lake like equal and so the lake balance equation simplifies to: If, $V_i = I$

$$P + V_a + V_d - E = \pm \Delta W$$

3. LAKE LEŞU WATER BALANCE

At Lake Leşu (Fig. 9), the water balance indicates a pluvio-nival regime. The maximal values of the water balance are reached in April-May when snow melting is correlated with the spring rainfalls. Another maximum is reached in September as a result of the June-July heavy rainfalls. The precipitations multiannual average values are rather high in this area – 1265,6 mm.

The pluviometric regime reveals a second maximum in December, because of the important solid precipitations, its importance in this context being related to its implication in the spring maximal runoff (due to the snow melting).

The evaporation values are much under the precipitation ones, the argument standing in the lake's high altitude associated with decreased temperatures, abundant precipitations and high cloud cover values. During winter months, the evaporation is totally missing because of the lake water freezing.

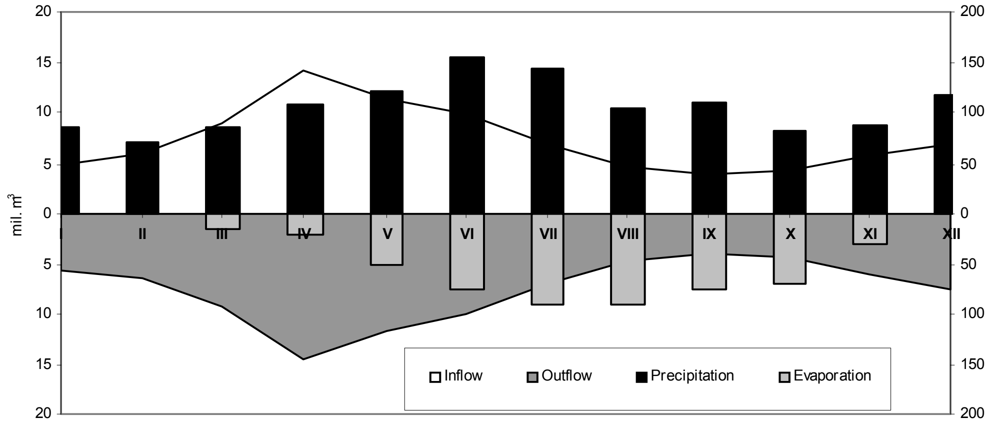

Fig. 9 . Average water balance of Lake Leşu

Because the balance was computed from multiannual monthly data, the redistribution of retained volumes could not be followed and that is why we had to use data that characterize smaller periods (yearly values) (Fig. 10).

We observe that the natural runoff distribution is completely modified, the maximums are retained in the lake volume and restored to the runoff only when the beneficiaries need it.

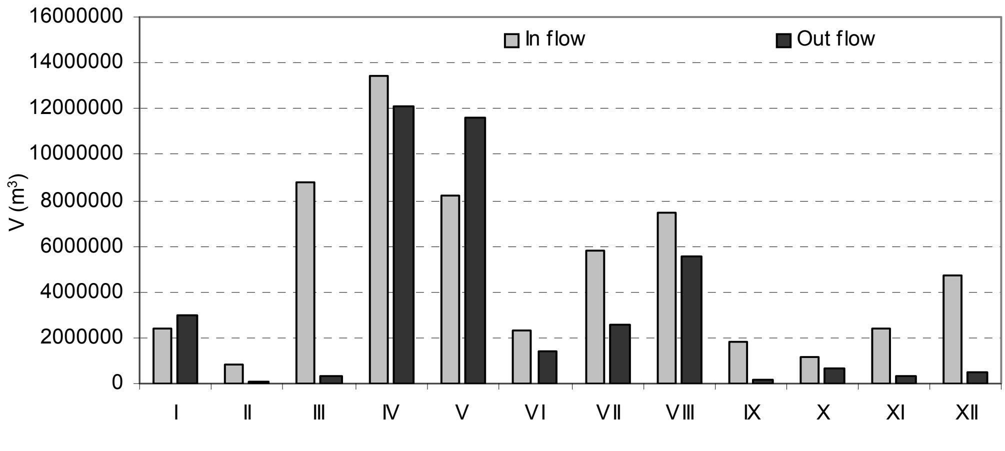

Fig. 10 . Volume redistribution by the dam discharge at Lake Leşu (2005)

The main elements of the lake hydrologic balance are the affluent and the deffluent discharges, which contribute with 98-99% to the annual water volume. At the same time, the possibility of stocking such a quantity of waters in storage lakes allows a discharge distribution throughout the whole year. As a result of their primary functions, the variation of the water volumes is related to the population water demand.

In case of the water balance of Lake Leşu, the principal function of hydroenergetic power generation joins extremely well with the redistribution of maximum volumes, in consequence the floods number in the basin decreased and the possibility to satisfy the water needs of the beneficiaries became greater growth.

References

Chiriac, V., ş.a. (1976), *Lacuri de acumulare*, Editura Ceres, Bucureşti.

Gâştescu, P. (1971), *Lacurile din România. Limnologie regională*, Editura Academică, Bucureşti.

Gâştescu, P. (1998), *Limnologie şi oceanografie,* Editura H.G.A., Bucureşti.

Pandi, G. (2004), *A Gyilkos-tó. Hidrogeográfiai tanulmány*, Casa Cărţii de Ştiinţă, Cluj-Napoca.

Pandi, G., Horvath, Cs., Vigh M. (2004), Modelerea timpului de schimbare a volumului de apă în Lacul Roşu, in Volumul *Conferinţei Ştiinţifice Anuale a Institutului Naţional de Hidrologie si Gospodărirea Apelor*.

Simona, Rusu (2004), *Aspects regarding water surface evaporation in Romania*, INMHGA, Bucureşti.

Sorocovschi, V. (2002), *Hidrologia uscatului, I – II*, Editura Casa Cărţii de Ştiinţă, Cluj-Napoca.

Stelcher, K. (2000), *A vízkészlet-gazdálkodás hidrológiai alapjai*, ELTE Eötvös kiadó, Budapest.

Teodorescu, I. ş.a. (1976), *Lacuri de acumulare*, Editura Ceres, Bucureşti.

Ujvári, I., Gâştescu, P. (1958), Evaporaţia de pe suprafaţa lacurilor din R.P.R., Rev. *Meteorologia, Hidrologia şi Gospodărirea apelor*, an 3, nr. 1, pag. 49-56, Bucureşti.

http://www.esri.com/