THE ANALYSIS OF THE SILTING PROCESS OF VÂRŞOLȚ RESERVOIR

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ABSTRACT. – The Analysis of the Silting Process of Vârşolț Reservoir. The silting process of Vârşolț reservoir has been monitorised beginning with the year 1983. The successive hydro-topometric surveys done in 1983, 1985, 1989, 1991, 1995, 1997, 2002, 2009 and the resulting data were reported to the initial morphometric characteristics of the lake, for the period 1979 – 2009 and to the one obtained out of the following topographic surveys. The methodology consists in determining the evolution of the silting of the Vârşolț reservoir by calculating the characteristic volumes: dead volume, available volume, flash flood protection volume, above overflow volume, attenuation volume, global volume and the global volume corresponding to the height of the dam. The period 1979-2009 notes a global silting volume in the reservoir of 7,852 million m³, representing 16,43% of the initial volume. Analysing the silting of the characteristic volumes in the mentioned period one can notice that in the first 12 years (1979-1991) the process was very intense, and considerably diminished in the last 18 years (1991-2009). The determination of the sediment volume reaching the reservoir was done by means of the solid discharge measured at Crasna hydrometric station between 1981-2009. The volume of sediments accumulated in the reservoir resulting from the difference between the volumes at a normal service level in 1979 and 2009 is of 5.71 million m³. The silting degree corresponding to this volume is of 26,5%, with an average annual silting rate of 0,59%.

Cuvinte cheie: suspended load**,** characteristic volumes, silting rate, silting degree

1. Introduction

Vârşolț reservoir in situated in the western part of Sălaj county, in the piedmont Depression of Crasna, overlapped in its turn to the eastern part of the Şimleu Basin (Fig. 1). It was built after closing up the Crasna River at aproximately 1 km upstream of Vârşolț village, 1 km downstream of the confluence of Crasna River with Mortăuța brook and at a distance of 96 km from the border with Hungary (Şerban, Gh., Mirisan, B, Câmpean, I., Selagea, H., 2010).

Vârşolț reservoir was operated in two stages: stage I in 1978 and stage II in 1979. It was built for flash flood attenuation on Crasna River, the drinking water supply of Zalau and Şimleu Silvaniei, sport fishing.

The reservoir is V shaped, with the Crasna branch 3 km long and 1.3 km wide and the Colițca branch 3 km long and 1.5 km wide.

The surface of the reservoir at a normal retention level is of 456 ha, and at the level of the height of the dam the surface is of 767 ha. The global volume of the lake is of 39,39 mil m³, while the attenuation volume is of 23,33 mil. m³.

The dam was built of materials found nearby, especially clay. The dam is 2160 m long, 5 m wide and has o maximum height of 14 m. The dam delineates a basin with a surface of 345 km² (Pandi, G., Şerban, Gh., Vigh, M., 2012).

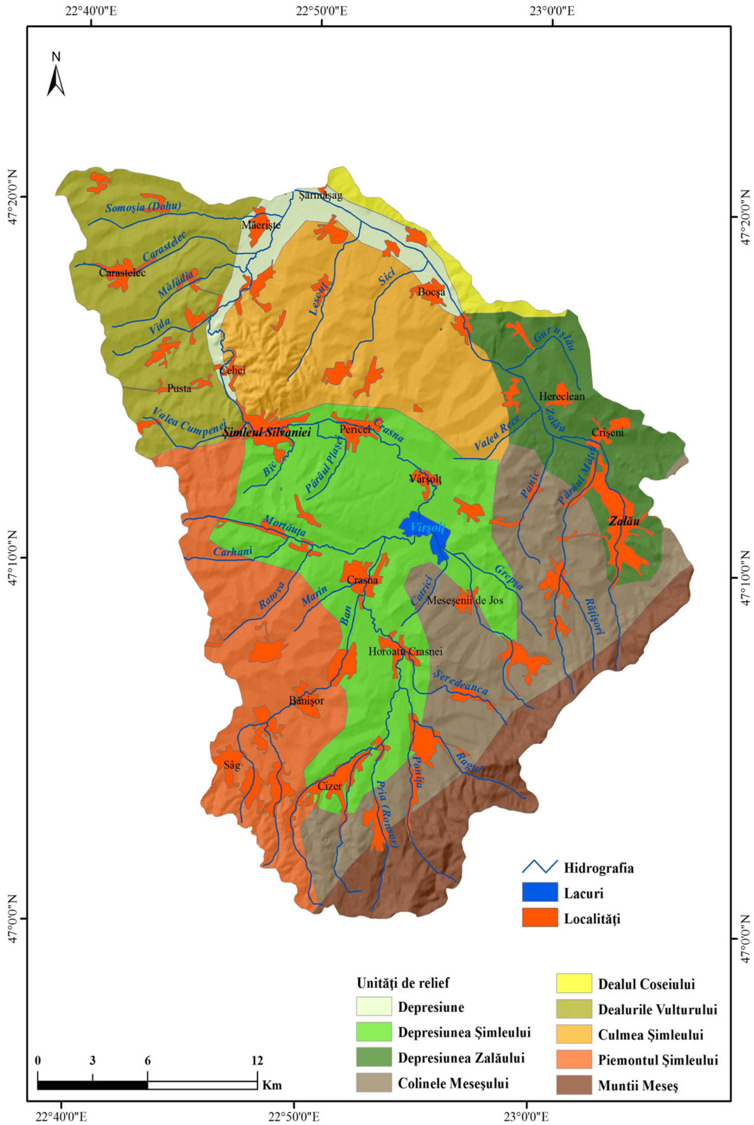

Figure 1. The map of the relief units in the Crasna Basin until the confluence with Zalău.

Regarding the geology of the settlement, according to the Operating Rules of the Vârşolţ Reservoir issued by Romanian Waters, the left slope is made of terrace deposits consistingof a layer of sands, sands with gravel and elements of stones, under which is developped a layer of clays, made of clays and dusty clays, very wet. The foundation is made of sedimentary deposits from the meadow of Crasna River made of dark brown clays under which one can found a layer of sands with gravel and rare elements of stones.

Among the factors which influence the suspended load and the silting process of the reservoir we mention here the geological substratum, the relief, the vegetation coverage (land-use), the liquid flow.

The suspended load varies with the altitude, resulting that at altitudes between 400 – 500 m the maximum values are reached (6 – 6,5 t/ha/an). This value decreases both at higher altitudes, where the substratum is more less erodable, and at lower altitudes, where water erosivity is weaker. Also in this altitudinal span the maximum turbidity is recorded (3-4 kg/mc) (Diaconu, C, 1971, cited by Pandi, G. 1997). In the Crasna Basin this altitudinal span occupies rather limited areas (Fig. 2)

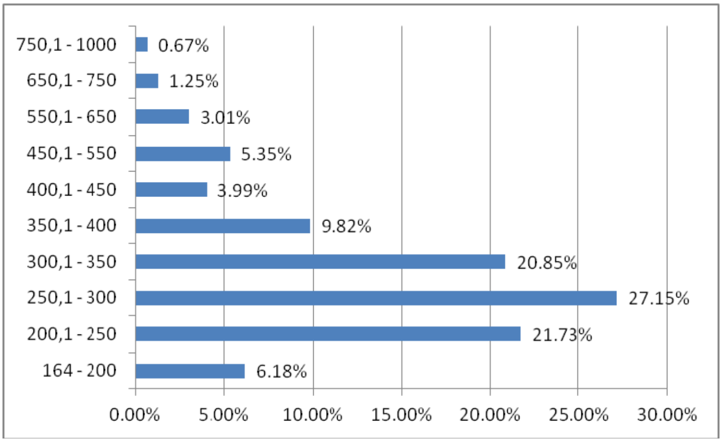

Figure 2. The percentage of the altitudinal spans in the Crasna Basin

The slope influences the surface and depth erosion, the occurrence of land-slides, the aggradation of the valley bottoms. Besides petrography and structure the slope conditions the intensity and the type of processes that shape the relief. This shows the strong influence that slope has upon the silting process. From the point of view of the conditions that trigger surface erosion (after Moţoc, 1983), the agricultural lands situated on slopes over 5° are the most exposed surfaces, which in the Crasna Basin occupy important areas (Fig. 3). The slope also influences the velocity of the water current and the surface and subsurface flow. High values favor the rapid growth

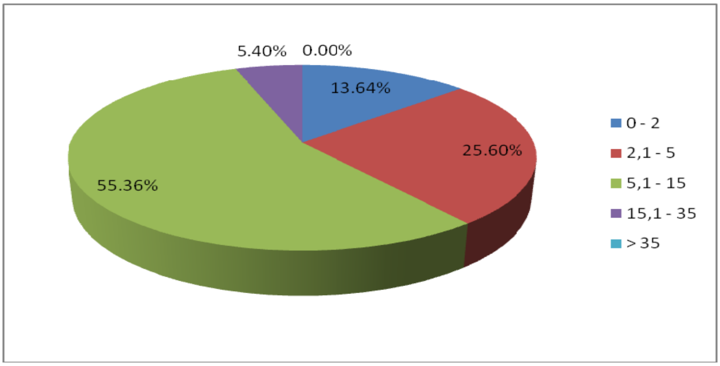

Figure 3. The percentage of surfaces with various slopes in the Crasna Basin

of discharges and the occurrence of floods, periods when the solid load is maximum, the highest silting rates being also recorded.

Land-use (Fig. 4) influences the sediment yield and implicitly the silting of the Vârşolţ reservoir, the forested areas offering the best protection against surface erosion, while the agricultural lands are the most predisposed to the degradation processes.

The large surfaces occupied by the agricultural lands (unirrigated arable lands, mainly agricultural lands, areas with complex cultures) (41,18%) inside the basin explain the favorability of the surfaces denudation.

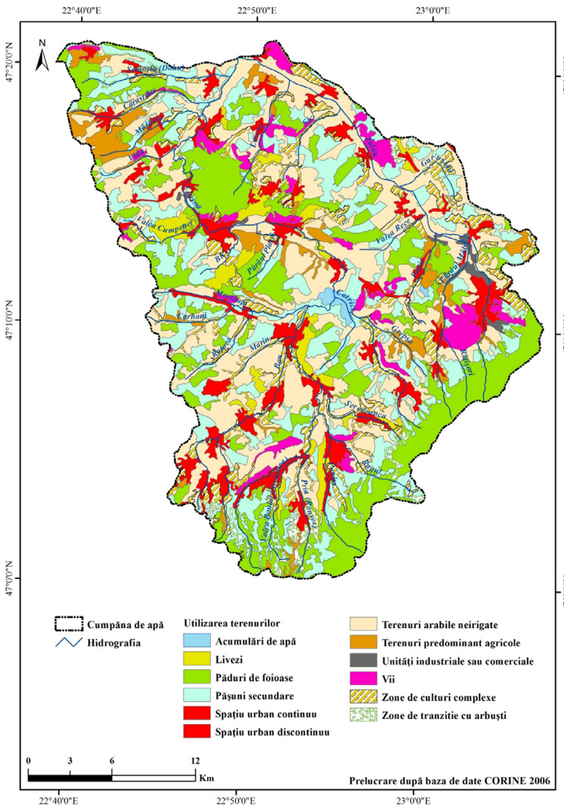

Figure 4. The map of land-use in the Crasna Basin.

2. Methodology

The analysis of the silting process of the Vârşolţ reservoir was done by means of successive hydro-topometric surveys accomplished by Someş – Tisa Water Branch, SGA Sălaj, beginning with the year 1983, continuing in 1985, 1989, 1991, 1995, 1997, 2002 and 2009. The resulting data have been compared both to the initial morphometric characteristics of the lake for the period 1979 – 2009, and to the ones resulting from the following surveys.

The determination of the sediment volume reaching the reservoir was done by means of the solid discharge measured at Crasna hydrometric station (the only hydrometric station on Crasna River in Sălaj county where the solid discharge is being measured) between 1981-2009.

The evolution of the silting process of Vârşolţ reservoir has been outlined for the characteristic volumes: dead volume, available volume, flash flood protection volume, above overflow volume, flash flood attenuation volume and global volume.

According to Someş – Tisa Water Branch for the calculation of the characteristic volumes the following levels were used:Talweg level: 228,0;Minimum service level (NmE): 232,5;Normal service level (NNR): 240,0; Top overflow level: 242,0; Maximum service level (NME): 243,94; Dam level: 244,5

3. Results

The suspension load flow

The main factor that influences directly the silting phenomenon is the suspension load discharge brought by the lake's tributaries. This is strongly connected to the precipitation and the liquid discharges (Horvath, C., 2008).

Analising the monthly variation of the average solid discharge (Fig. 5) one can notice that the highest values are recorded in May, when there is carried out over a quarter of the global sediment load (25.66%). High values are also recorded in March, April and June when there is carried out 40.15% of the annual sediment load. The great sediment volume carried out during spring and early summer is due to a series of factors such as: heavy torrential rainfall recorded in this period, snow melting, high liquid discharge, the soil not yet covered by vegetation.

Compared to the monthly variation of the liquid discharge (Fig. 6) measured at crasna station for the same period (1981 – 2009) one can notice that the maximum values are recorded aproximately in the same months: March (15.23%), followed by April, June and May. In this period is been carried out 47.64 % of the average annual discharge.

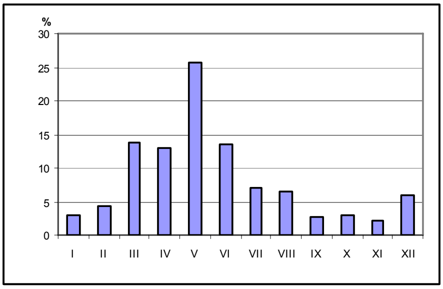

Figure 5. The monthly variation of the solid discharge at Crasna between 1981-2009

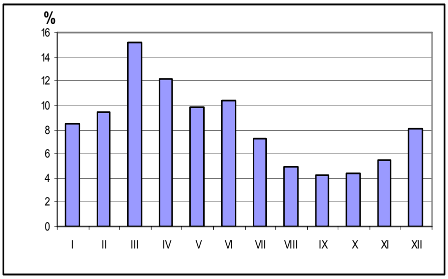

Figure 6. The monthly variation of the liquid discharge at Crasna HS between 1981-2009

Regarding the monthly repartition of the precipitation fallen at crasna station (Fig. 7) one can notice that in this case the highest values are recorded during the summer, with a maximum in July (13.81%), followed by June, May and August.

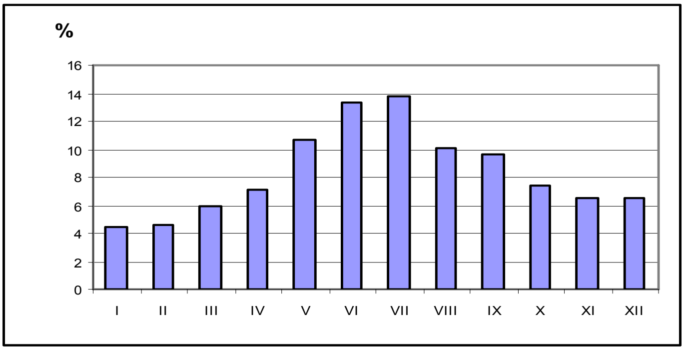

Figure 7. The montly repartition of the average precipitation fallen at Crasna station between 1986 – 2009

Regarding the annual repartition of the solid discharge in the analyzed period (Fig. 8) the highet annual average values were recorded in 2006 (15,315 kg/s), followed by 1985 (13,091 kg/s), 1989 (8,5395 kg/s), 1997 (5,9054 kg/s) and 2001 (5.1836 kg/s). Analyzing the climatic context in which these values were recorded we need to mention that taking into consideration the weighted anomaly standardized precipitation (WASP) the marks for these years are: normal (2006 and 1985), little rainy (1989 and 1997) and moderate rainy (2001).

The lowest average annual values of the solid discharge during the analized period were recorded in 1994 (0,5117 kg/s), 1990 (0,5126 kg/s), 2007

(0,5891 kg/s), 2003 (0,6951 kg/s) and 1983 (0,6965 kg/s). The pluviometric characterisation of these years according to the value of WASP is: little dry (1994 and 2003), moderate dry (1990), normal (2007) and moderate rainy (1983).

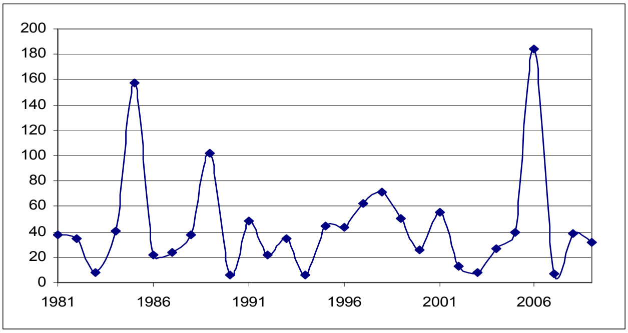

Figure 8. The annual variation of the solid discharge at Crasna HM between 1981-2009

Out of the multiannual value of the suspension load discharge (3.684 kg/s) results the fact that its value reaches 116,178.6 tons/year, while the value of the average specific suspension load discharge is of 5.920 t/ha/year.

The characteristic volumes dynamics under the effect of the silting phenomenon.

The evolution of the characteristic volumes of Vârşolţ is shown in values in Table 1 and graphically in Figure 9.

Table 1. The evolution of the chracteristic volumes of Vârşolţ reservoir between 1979-2009 (mil. m³) (source Someş-Tisa Water Branch)

Year	1979	1983	1985	1989	1991	1995	1997	2002	2009
Dead v.	0.592	0.279	0.183	0.117	0.084	0.081	0.048	0.0005	0.000
Available v.	20.908	18.371	17.877	16.783	16.687	16.449	16.358	16.0695	15.7886
Flash flood protection v.	11.900	11.224	11.220	10.840	11.138	10.460	10.367	10.460	8.6233
Above overflow v.	14.400	14.626	14.400	12.955	13.041	12.870	12.874	12.858	15.5364
Flash flood attenuation v.	26.300	25.850	25.620	23.795	23.879	23.330	23.241	23.318	24.1597
Global v.	**47.800**	**44.500**	**43.680**	**40.695**	**39.650**	**39.860**	**39.647**	**39.388**	**39.9483**

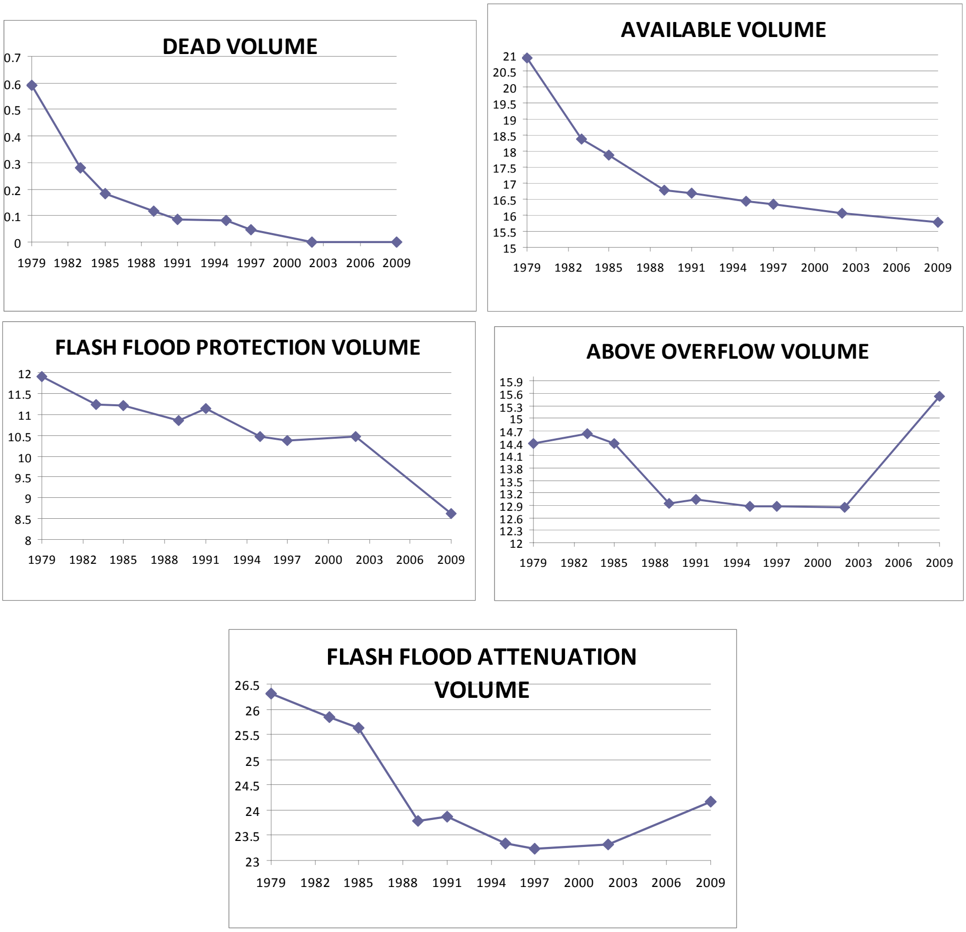

Figure 9. The evolution of the characteristic volumes of Vârşolț reservoir betwen 1979-2009.

4. Discussion

Analyzing the silting of the characteristic volumes between 1979 – 2009 one can notice that in the first 12 years (1979 – 1991) the process was very accelerated and considerably diminished in the last 18 years (1991 – 2009).

The dead volume has been silted between 1979 – 1991 in an extent of 85,8%, and it was completely silted by 2009.

The available volume has been silted between 1979-1991 in an extent of 20,2 % and of 24,5% on the entire period.

Regarding the flash flood protection volume it has been silted less during the first period (1979-1991) – 8,9% and more during the last years, reaching at a rate of 26,8% for the entire period.

The global volume has been silted in an extent of 15% between 1979-1991 and of 16,4 % on the entire period. The silting degree of the global volume on the entire period is shown in figure 10.

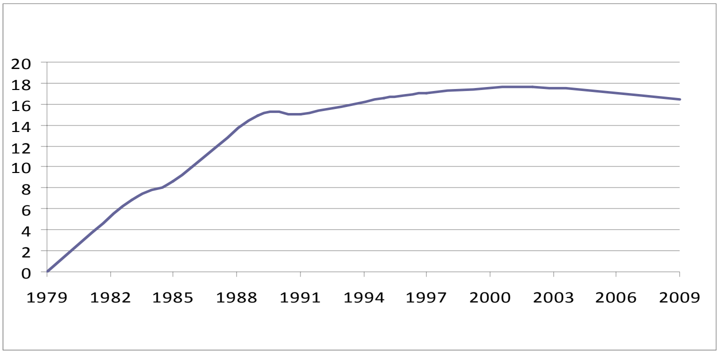

Figure 10. The silting degree of the global volume of Vârşolţ reservoir between 1979 – 2009.

The silting rate varies during the 30 years of functioning of the reservoir, being accelerated during the first years. It was reduced in the last period as a consequence of the reduction of the local erosion rate, the changes appeared in land-use, the reduction of land degradation by the land washing phenomenon. Another import factor for silting reduction is represented by the works of river beds improvement, of defense and strengthen of banks (Şerban, Gh., Mirişan, B, Câmpean, I., Selagea, H., 2010).

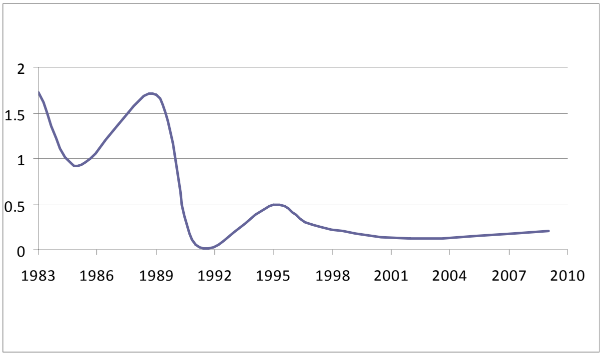

Figure 11. The evolution of the annual silting rate of Vârşolţ reservoir between 1979 – 2009.

The changes suffered by the lake's basin can be cuantifyed on basis of characteristic curves (of surfaces and volumes) at various levels.

Out of a comparative analise of the surface keys for the surveys done in 1995 and 2009 (Fig. 12)one can notice an abrupt reduction of the surface around the minumum service level (233 m) from 36.6 ha in 1995 to 0.0795 ha in 2009. Regarding the normal service level (240 m) the surfaces are almost the same, with a slight growth in 2009 (459.174 ha), as compared to 1995 (455.78 ha). Also a growth of the surface can be noticed for the maximum service level (244 m), from 716,5 ha in 1995 to 762.358 ha in 2009.

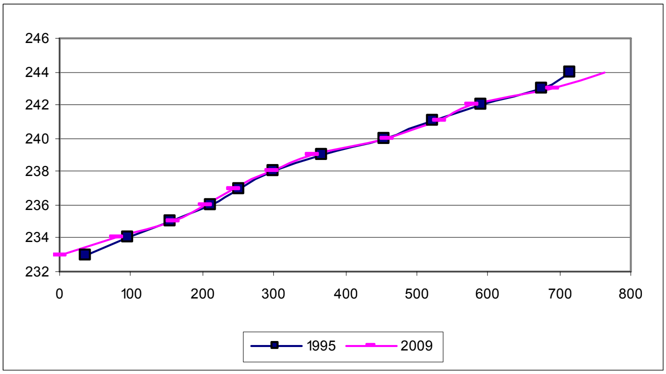

Figure 12. The surface key for Vârşolț reservoir

Regarding the volumetric key (Fig. 13) one can notice a decrease of the volume until the maximum service level, where there is a slight growth in 2009 (40.40 mil m³) as compared to 1995 (40.07 mil m³).

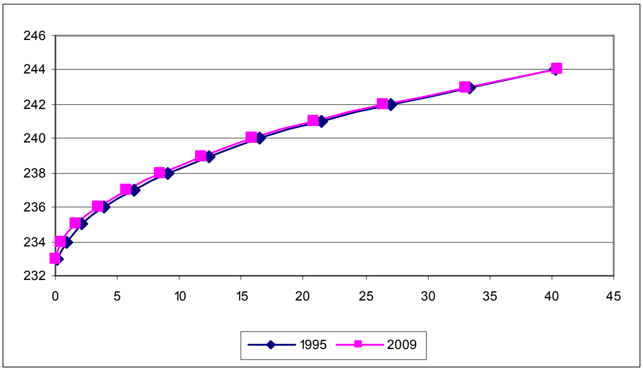

Figure 13. The volumetric key for Vârşolț reservoir.

6. Conclusions

The volume of sediments accumulated in the lake, calculated as the difference between the volumes at normal service levels in 1979 and 2009, is of 5.71 millions of m³, the corresponding silting degree being of 26.5%. The annual average silting rate is relatively low (0,59%).

We can draw the conclusion that the silting rate is not a very significant one also by calculating the silting time (Horvath, C., 2008), using the formula:

$$Ta = W / Wr,$$

where :

W = the initial volume of the reservoir

Wr = the volume of sediments silted in the reservoir during one year.

Applying the formula for the period 1979 – 2009 (30 years), when there were silted 5.71 mil m³, meaning 0.19 mil m³/year and an initial volume of 47.8 mil m³, results a silting time of 252 years, which means an acceptable span towards the characteristics of the reservoir's catchment area. One also has to take into consideration the fact the estimated life span of the reservoir has grown very much as compared to the one calculated for the first 12 years of functioning. Between 1979 – 1991 there were silted 4.73 m³ of sediments, meaning 0.39 m³/ year. The silting time calculated with these data is 123 years.

The growing of the life span of the reservoir is due both to the natural evolution of the phenomenon, being well known the fact that the greatest volume of sediments is silted in the first years of service, and to the human intervention by a series of works aiming the unsilting and the protection of the river bed and banks.

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