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ANALYSIS OF SILTATION TEMPORAL VARIABILITY IN FOUM ELGHERZA DAM, PROVINCE OF BISKRA (ALGERIA)

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EXTENDED ABSTRACT

L'interrimento degli invasi artificiali pone agli operatori enormi problemi la cui risoluzione può essere troppo costosa per le comunità che ne usufruiscono. I materiali depositati sul fondo degli invasi, che provengono principalmente dall'erosione dei bacini idrografici che drenano le aree circostanti, ne riducono progressivamente l'effettiva capacità. Nel 2007, l'Algeria contava 120 tra piccole e grandi dighe in funzione, con una capacità di 7 miliardi di m3 di acqua, ed un volume regimentato di 3 miliardi di m^3 all'anno. Sul fondo di questi bacini di invaso si stima si sia depositato circa un miliardo di m^3 di sedimento. La maggior parte delle dighe in Algeria ha una vita media di circa trenta anni, quando si tratta di serbatoi destinati alla fornitura di acqua potabile o all'irrigazione, i cui interessi socioeconomici giustificherebbero una garanzia di servizio illimitata. È importante prevedere il tasso di sedimentazione e proteggere queste dighe dall'interrimento che sembra molto rapido. Per diversi motivi, ricercatori e tecnici in molti casi si rivolgono all'uso di modelli empirici, specialmente in caso di mancanza o assenza di dati da misure dirette o per ragioni puramente scientifiche. Il bacino di Oued El Abiod si trova nel massiccio dell'Aurès e fa parte del grande bacino di Chot Melghir. La valle del Wadi labiod si origina dal Wadi Chenawra e dal Wadi Tkout, che formano dalla loro confluenza il Wadi Ghassira. Lo spartiacque è caratterizzato dalla sua dissimmetria. Con una parte montuosa a nord oltre i 2000 m di quota, il monte Chelia, e una parte di rilievo a sud molto più bassa di quota, il monte Al Habel con i suoi 295 m di quota, la valle copre un'area di 1300 km² e un perimetro di 200 km. L'area di studio si presenta come un'area geograficamente estesa appartenente ad una regione climatica semi-arida. Le formazioni litologiche sono caratterizzate dalla presenza di marne, calcari e arenarie. La densità della copertura vegetale è elevata nella porzione a monte e molto ridotta più a valle. Le aree circostanti sono prive di stazioni idrometriche e studi e di studi sull'interrimento, così che è stato necessario cercare un modello di stima dell'interrimento che si adattasse alle condizioni dell'area di studio. Il modello applicato è quello di Orth (1934), già utilizzato in alcuni studi sull'interrimento degli invasi. Orth partì dall'assunto che la capacità residua varia nel tempo secondo una legge esponenziale. La sua equazione di stima è ampiamente utilizzata in Algeria e in particolare è stata applicata allo studio di 16 dighe. I dati utilizzati in questo studio provengono da diverse fonti: ONM, ANRH e ANBT. Questo lavoro segue un approccio comparativo che tiene conto del confronto dei risultati della stima dell'interrimento con quelli misurati (rilievi batimetrici). I risultati dell'applicazione di questo modello hanno mostrato una concordanza tra i valori stimati e quelli misurati e la buona corrispondenza è stata testata dalla legge di Nash; confermando l'efficienza e l'importanza di questo modello nell'area di studio. Il trasporto solido specifico ottenuto è stato calcolato con la formula Sogreah, e l'erosione in alcuni anni ha un'evoluzione concordante con l'interrimento calcolato. L'erosione massima è stata registrata durante l'anno 2001 con una intensità di 621,68 T/km^2/anno. L'analisi dettagliata dello stato dell'interrimento ha permesso di proporre una diagnosi finale che esprime lo stato di fatto dell'interrimento. I primi anni di servizio attestano un'accelerazione dei fenomeni tra il 1950 e il 1967, periodo in cui l'invaso ha ricevuto 13,72 Mm^3 di sedimento. Questo valore rappresenta il 42,70% dell'interrimento totale. Con questo studio abbiamo notato che il bacino del Wadi labiod segue un comportamento variabile dell'erosione anche da un anno all'altro, come effetto dall'irrigidimento del flusso delle variazioni nel deflusso superficiale e delle piogge torrenziali. I risultati del calcolo sul trasporto solido specifico, confrontati con quelli del calcolo sull'interrimento hanno permesso di notare che la correlazione tra trasporto solido specifico e interrimento non è sempre presente in tutte le fasi, probabilmente a causa dell'effetto dei parametri coinvolti nel calcolo dell'erosione per ogni fase di stima. Tra il 1967 e il 1986 la diga ha avuto un ritmo regolare di interrimento con un volume complessivo di 10 Mm^3, mentre il tasso di interrimento negli ultimi anni di servizio è diventato più regolare è relativamente basso. Questo lavoro ci ha permesso di avere un'idea sull'efficacia dei modelli empirici nel controllo e nella predizione dell'interrimento degli invasi artificiali. Tuttavia, questi modelli richiedono la conoscenza di tutte le condizioni e dei requisiti per l'applicazione. Aree vicine alla zona studiata e con condizioni simili possono trarre beneficio dai risultati ottenuti in questo lavoro e prendere seriamente in considerazione questo modello per la previsione e la stima dei volumi di interrimento. La disponibilità di rilievi batimetrici facilita l'analisi e la conoscenza dell'evoluzione dei processi di sedimentazione e aiuta i decisori e i tecnici a mettere in atto le strategie di predizione, prevenzione e gestione dei processi di interrimento, in modo sistematico e nel tempo necessario. La rimozione dei sedimenti dall'invaso e le opere di controllo dell'erosione rimangono i due mezzi più efficaci per la manutenzione delle dighe, al fine di recuperare parte della capacità di stoccaggio e garantire alle dighe una lunga durata, nonostante i costi più elevati.

ABSTRACT

The majority of dams in Algeria have some thirty years lifetime, when it comes to tanks intended for drinking water supply or irrigation whose socioeconomic interests justify an unlimited service guarantee. It matters to predict the water retention filling rate and protect these dams from siltation that seems very acute.

This paper deals with the problem of siltation in Foum Lgherza dam, in the East Algeria. We attempt to identify siltation behavior according to a detailed analysis based on the comparative approach between results obtained by a projected relationship for the study area, and the measuring results obtained by bathymetric surveys, both of results are very close and determine the aggressiveness of erosive balance and accelerated siltation.

***Keyword**: accelerated siltation, comparative approach, bathymetric surveys, foum lgherza dam*

INTRODUCTION

Sedimentation rate has increased during these last years, because of strong catchments erosion. By the early Eighties, nearly 120 million tons of sediments have been, yearly, pulled out in the North Algeria catchments (Demmak, 1982). Water retentions siltation, in Algeria, has reached high volumes and poses, thus, serious problems. This is, mainly, due to the high rates of erosion in these dam's catchments, and to the underestimation of sediments quantities that might settle during their conception Heush & Millies (1971). In this paper, we present a mathematical model that allows to estimate volumes of sediments reaching water retentions. Decrease in hydraulic structures water storage has been seen, constantly, increasing, over these last years due to the two following reasons: the first one, of natural origins, is encouraged by climate aggressiveness, alternation of dry and humid periods, frailty of geological formations and luck of sufficient vegetation cover; mean while the other is due, on the one hand, to the bad problem studies and evaluations before constructing dams, which allows to predict solutions before the occurrence of the phenomenon effects (Hadji & Chadi, 1991). According to the ICOLD World Register of Dams (2009), there are 114 large dams in Algeria. Thus, 35% of dams are represented by the average sediment yield rate.

On the other hand, it is due to the bad exploitation of ancillary structures, such as sluice gates and racking structures (Remini *et alii,* 1996). Numbers reviewed bellow illustrates better the size of this problem in Algeria. The decrease of Algeria's hydraulic potentialities after siltation are, yearly valued at 20 million m^3 (SAIDI, 1991)

Solid transport calculation and siltation volume prediction require a good comprehension of the phenomena of their genesis, and more particularly, the one of soils erosion. Indeed, solid transport is the main driving force after erosion, leading to dam's siltation process. This process makes the link between catchment soils and dam accumulated water (Brambilla *et alii,* 2015). Solid particles will be carried in suspensions or in thrusts. In suspension transport, the elementary solid particles move in suspension within discharge with a similar speed as that of the fluid, where the turbulence maintains thin elements in suspension.

Accelerated sedimentation of dam accumulated water was evident since starting the realization of the dam (Touat, 1991). Reservoir siltation affects the safety of old reservoir in several ways. The sediment in the reservoirs increases the load on the wall of the dam. The reduction in storage capacity reduces the attenuation of the flood and it may increase outflow (Mama & Okafor, 2011).

Upstream cofferdam has been, completely, filled in two years (1948-1950); afterwards, it has caused a speed climb of silt roof, i.e., 35 meters in 40 years of exploitation, that presents a silt volume equal to 21 Mm^3. We estimate the water retention capacity in 1995 by 20 Mm^3, i.e., more than 50% of filling.

Dam's management requires a forecast study on sediments deposits for the actualization of the curve "height/capacity". Siltation prediction is a crucial step for each dam feasibility project (Brune, 1953). Regular following-up of solid tanks in a dam is necessary for water retention eventual desilting. Orth's model is largely, applied on Algerian dams, and the results of this model have been compared to siltation measures made on this water retention (SAIDI, 1991; Touat, 1991). dams are vulnerable to degradation in capacity and safety due to the deposition of solid material inside the reservoir (Brambilla *et alii,* 2015). The control of dams' basins siltation allows, on the one hand, to supervise structures and to decide protection measures to be taken; it leads to a global estimation of solid transports and erosion phenomena in catchments.

PRESENTATION OF THE STUDY AREA

The watershed of Oued El Abiod is located in the Aures massif (Fig. 1a). It makes part of the large hydrologic basin of Chot Melghir that is composed of three main wadi: Wadi El Abiod, Wadi Chenawra and Wadi Tkout, forming by their confluence Wadi Ghassira (Fig. 1b). Wadi El Abiod is formed by gathering torrents descending from steep slopes of Chelia 2,326 m and Ichemoul 100 m. Aftercrossing Tighanimine, it stands in Ghoufi canyons and the gorges of Mchouneche, then a way opens towards the Saharan plain, until the gorges of Foum El Gherza. The catchment is characterized by its dissymmetry; a mountainous part at the north with more than 2,000 m Chelia, and another low at the south with 295 m El Habel. It spreads on 1,300 km² circumscribed by a perimeter of 200 km.

The study area, is presented as a geographically extended space belonging to a semiarid climatic field.

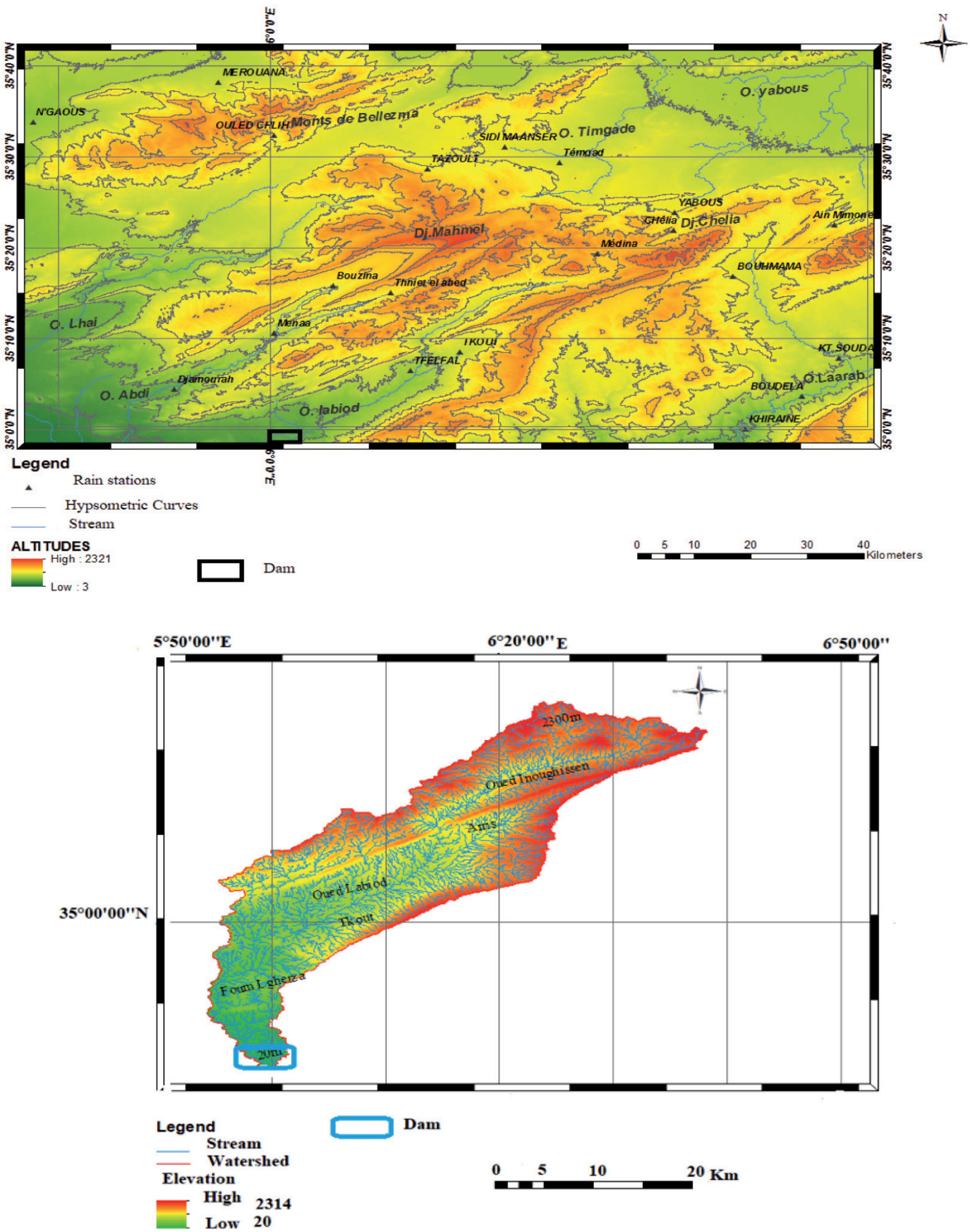

Fig. 1 - (a) situation of the study area according to the hypsometry; (b) situation of the study area according to the watershed

METHODS AND MATERIALS

Data and methods

The data used in this study come from different agencies responsible of hydraulic projects management, control, and following-up:

ONM (Weather National Office): pluviometric data source (the following pluviometric stations: Medina, Tkoute, Tifelfel).

ANRH (National Agency for Hydraulic Resources): source of debits and pluviometric data (dam's station)

ANBT (National Agency for Dams and Transfer): dam's data source (results of bathymetric records: observed capacities and siltation).

To determine siltation evolution in the dam of Foum Elgherza, over time, we have used results of six bathymetric surveys made during siltation period (1950-2010), every survey interprets the siltation behavior in a stage. We considered appropriate to make comparative study between obtained results by the forecast relationship, the measure of bathymetric surveys and the results given by Orth's relation. The choice of this formula is justified by the fact that it is the commonly used relation in Algeria (SAIDI, 1991).

The comparison explains the variability with siltation factors.

ORTH (1934) studied the prediction of siltation. He assumed that the residual capacity varies over time and according to an exponential law. The formula is widely used in Algeria.

Orth's formula was applied on 16 dams in Algeria.

The results were as follows:

56% of cases has a medium absolute deviation < to 5%

81% of cases has a medium absolute deviation < to 10%

18,7% of cases have a medium absolute deviation > to 10%

The suggested formula has given good results which makes it applicable.

Formula's parameters

The first who has described this process is ORTH (1934), he was suggested that the residual capacity varies in time according to a law with an exponential decline; it means that after many years of exploitation it is equal to:

$$C_t = Cnwr\ a^t \qquad (1)$$

C_t is the residual capacity after time "years of service";

Cnwr is the capacity of normal water retention (in hm³);

a is the parameter of each dam;

t is the number of exploitation years.

It can be written: if *Vst* is the envased volume after many years,

$$Ct - Cnwr - Vst = Cnwr\ a^t \qquad (2)$$

$$Vst = Cnw\ (1- a^t) \qquad (3)$$

a = 0.981 for our basin;

t is the number of years;

Ys is the materials weight ys=1.6 t/m³;

With

$$Qs = Cnwr\ (1-a) \qquad (4)$$

where *Qs* is the sediment discharge (in hm³).

The forecast formula becomes:

$$C_t = Cnwr\ (1 - Qs/Cnwr)^t \qquad (5)$$

v is the volume of the siltation is equal to

$$v = Cnwr - C_t \qquad (6)$$

The estimate of the siltation of the dam by the Orth method is in agreement with the sedimentary volumes observed.

SOGREAH's formula (1989)

Based on data received in 27 basins of Algeria (16 of them feeding supplying dams), surfaces vary from 90 to 22,300 km², Sogreah's relation is inspired from TIXIRONT's relation (1980), it gives the specific solid (in t/km²/year) according to the surface flow (in mm) and basins permeability.

High $Sd = 8.5 \cdot R^{0.15}$ (7)

Medium to high $Sd = 75 \cdot R^{0,15}$ (8)

Weak to medium $Sd = 350 \cdot R^{0.15}$ (9)

Weak $Sd = 1400 \cdot R^{0.15}$ (10)

Impermeable $Sd = 3200 \cdot R^{0.15}$ (11)

where Sd is the specific degradation sediment load (in t/km²/year).

The formula that matches better, to the morphometric and rock characteristics of the studied basin is the third formula (9).

RESULTS AND DISCUSSIONS

Results obtained

Results obtained on calculated siltation was presented in Tab. 1 and Fig. 2.

The examination of the graph and the table 1 showed a very speed siltation rate between 1950 and 1986, with a quantity of 23.89 Mm³ of sediments, meanwhile this acceleration declined and indicated a mitigation, starting from the year 1986 until the year 2009, where siltation, during this phase, reached 11.08 Mm³ (Tab. 5).

Both noticed remarks allowed to identify two distinct stages,

Year	1967	1975	1986	1993	2001	2009
Siltation (Mm³)	13.72	18.46	23.89	26.00	29.67	32.13

Tab. 1 - Evolution of the dam siltation (1967-2009)

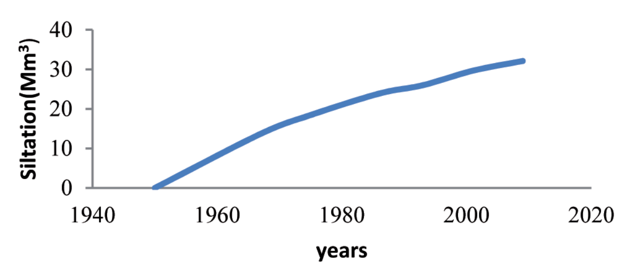

Fig. 2 - Evolution of the calculated siltation

the first stage indicated an acceleration of siltation, the second was relatively weak. The analysis of these observations comes to confirm the results of conducted studies in many Algerian dams, as for the siltation acceleration in the first years of exploitation and mitigation in last years (Hadji & Chadi, 1991; Remini & Hallouche, 2003).

The following figure gives the comparison of measured and calculated annual siltation of the dam.

The model obtained is interpreted by a very significant correlation coefficient that reached 0.95, this correlation can be explained by the homogeneity and the concordances of the data involved in the calculation formula (Fig. 4) expresses the relationship between noticed capacity and calculated capacity.

The figure 4 shows the existence of a strong link between the noticed and the calculated data. The correlation coefficient is of the order of 0.98 and the adopted formula for erosion calculation, takes into account the yearly rain and permeability as determinant factors.

Erosion processes acceleration and solid transports depend fundamentally on hydrological and morphological conditions of watershed.

Siltation is purely related to annual rain and to permeability of rock formation (Tab. 2).

It should be noticed that calculated siltation seemed very close to the observed siltation. In the case of this basin, a difference of 3.09 Mm³ recorded. These results are comparable to those presented by some authors (Remini & Hallouche, 2003).

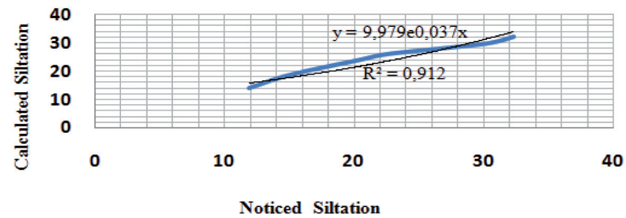

Fig. 3 - Comparison of measured and calculated annual siltation

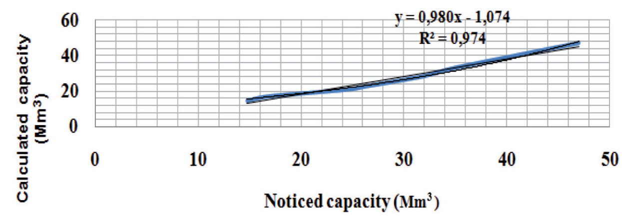

Fig. 4 - Correlation between noticed capacity and calculated capacity

Fig. 5 explains the relationship between observed and calculated volumes

The superposition of the results of the volumes observed and those estimated expressed the consistency of the model chosen. This model remains effective and applicable in comparable conditions and in neighboring areas, especially in the absence of measurements.

YEARS	ANNUAL RAINFALL (mm)	ANNUAL FLOW (mm)	SEDIMENT TRANSPORT (T/km²/year)	SILTATION (Mm³)
1967	*370.48*	*43.9102103*	*617.238303*	*13.72*
1975	*280.51*	*16.6446055*	*533.653142*	*18.46*
1986	*350.48*	*36.8267968*	*601.163544*	*23.89*
1993	*340.64*	*33.5527755*	*592.826095*	*26.00*
2001	*376.26*	*46.0634959*	*621.686703*	*29.67*
2009	*347.10*	*35.686401*	*598.333-69*	*31.13*

Tab. 2 - Calculation results of specific erosion equation

YEAR	TIME (years)	NOTICED CAPACITY (Mm³)	CALCULATED CAPACITY (Mm³)	NOTICED SILTATION (Mm³)	CALCULATED SILTATION (Mm³)	DEVIATION
1950	0	47	47	0	0	0
1967	18	35.07	33.28	11.93	13.72	1.79
1975	26	31.93	28.54	15.07	18.46	3.39
1986	37	26.52	23.11	20.48	23.89	3.41
1993	44	24.32	21.00	22.68	26.00	3.32
2001	52	16.90	17.33	30.01	29.67	0.43
2009	60	14.74	14.87	32.26	32.13	0.13

Tab. 3 - Noticed and calculated dam data

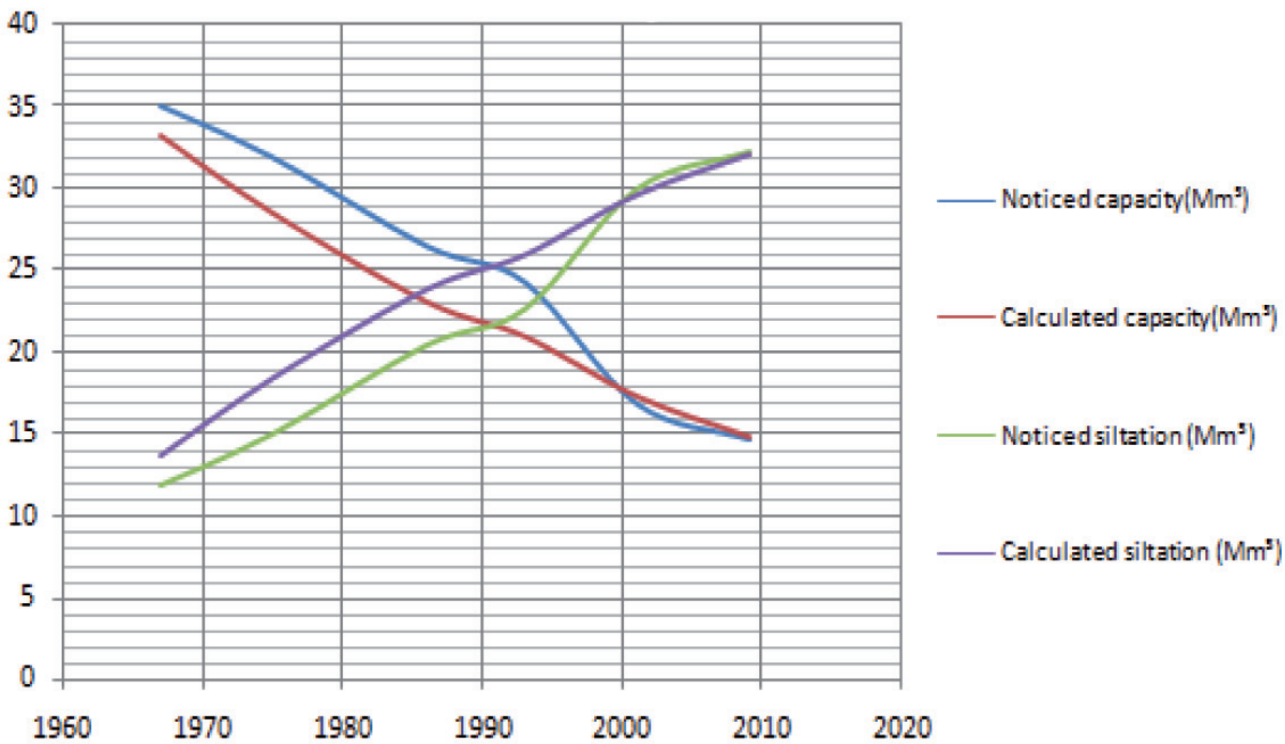

Fig. 5 - Comparison between the noticed and calculated volumes

Test and validity of the data

The criterion of Nash & Sutcliffe (1970), based on the mean squared error is very commonly used as objective function.

The Nash criterion function was used to determine the mean squared difference between a reference curve (Yref (x)) and a simulated curve (Ymod (x))

$$Nash = [1 - \sum(Vca - VObs)^2 / \sum(VObs - \overline{VObs}^2)] \quad (14)$$

($\overline{VObs}$): average siltation for each bathymetric level;
VObs: siltation observed;
Vca: siltation calculated.

The following table sets out the Nash test that verifies compliance between measured and observed data.

If the value of Nash = 1: the estimation is perfect.

If 0 < value Nash <1: the estimation is better.

If the value of Nash < 0: the estimation is less.

The values obtained by applying this formula reflected a very good estimate (the simulated values correspond perfectly to the values observed). The result obtained confirms the correlations performed among the observed and calculated volumes.

This figure comes to present the comparison of some noticed bathymetric intakes.

YEAR	OBSERVED SILTATION (Mm^3)	CALCULATED SILTATION (Mm^3)	$(Vca-Vobs)^2$	$(Vca-\overline{Vobs})^2$
1950	0	0	0	358.398988
1967	11.93	13.72	3.2041	142.3249
1975	15.07	18.46	11.4921	227.1049
1986	20.48	23.89	11.6281	419.4304
1993	22.68	26.00	11.0224	514.3824
2001	30.10	29.67	0.1849	906.01
2009	32.26	32.13	0.0169	1040.7076
	18.9314286		37.5485	358.398988

Tab. 4 - Calculation results of Nash index

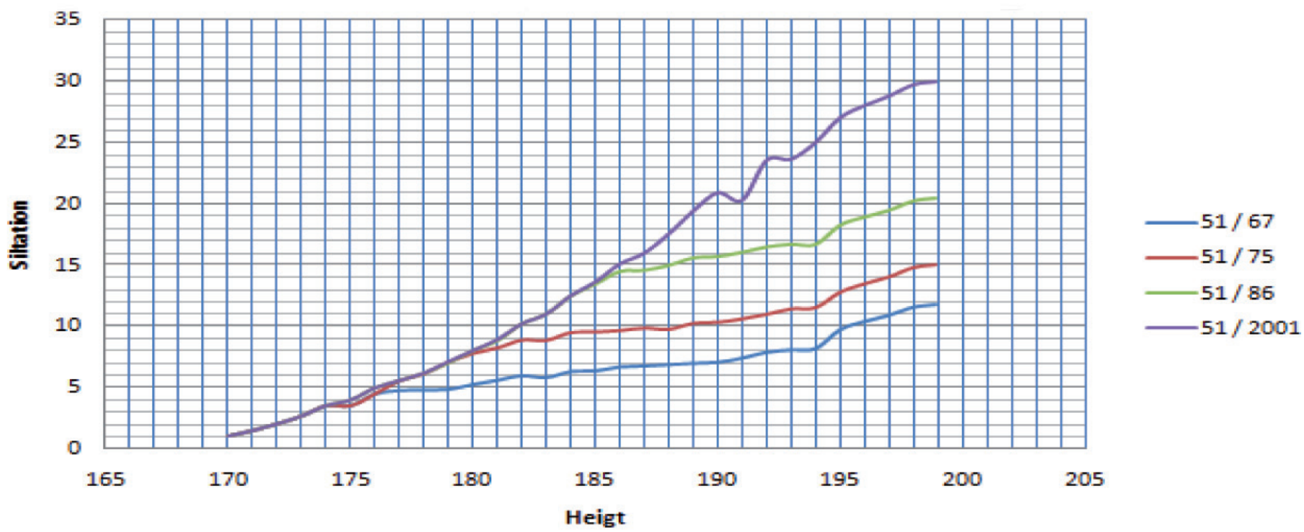

Fig. 6 - Comparison of some noticed bathymetric intakes

Discussion

The hydro-bathymetric results observed in the dam since its installation in 1950 were very eloquent. Figure 6 shows that dam capacity decreases and siltation increases with time. The upward evolution of the siltation process of the Foum El Gherza dam has become the dominant state.

The useful capacity in water retention is reduced by a few millions m³ (Tab. 5; Fig. 6). Since its entry into service, until 1967 the siltation estimated at 11.99 Mm³, or 23.40% of the total capacity of the dam. The comparison of the curves obtained showed a concordance between the values recorded and calculated.

Orth law is very effective and adaptable for estimating siltation in this dam. Before 1967, siltation was very important. The difference between measured siltation values gradually increased for the years 1967 and 1986, but with a relatively equal rate.

The analysis of different bathymetric surveys allowed to sum the siltation data up by stage, and for every reached altitude level.

The total volume of deposits in the dam represents a very high rate; the amount of the disposed alluvia during the first year of siltation is, equally. very high: about 10 Mm² between the levels 170 and 184, what explains the accelerated siltation character.

The sedimentation indicated mitigation, especially between 1975 and 1986, with an amount of 4.80 Mm³.

Last year's recorded a very remarkable increase with a deviation of 10 Mm³.

Deep observation of siltation curves evolution has allowed to detect a breakdown in sedimentation at the level of 190 m correspondent to the stage 1986-1993 (Fig. 6; Tab. 4).

The final diagnosis of siltation provided the analytical profile (Fig. 7).

Table 5 shows the final analytical state of the evolution of siltation according to the different slices of height in the dam.

The examination of the Tab. 5 and Fig. 7 shows the existence of three main stages of siltation according to duration and dam's height.

The first stage represents the very high-level rate of filling, accumulation occupies altitudinal level of 170 at 183 m during the first years, this category explains a sedimentation acceleration of 11.99 Mm³ (Tab. 4).

The second stage, relatively long, is characterized by a low sedimentation, this stage records, in the 25 years, a deposed amount similar to the previous stage. The stage of very low sedimentation rate corresponds, only, to the surface altitudes 8 Mm³ of silt is stagnated at this level.

Knowledge about siltation activity is of a big utility for hydraulic service, for exploitation and intervention (Bouzid, 1991). Priority in order to struggle against siltation. They may have an idea about dam's sedimentation speed, in order to take it into account during dam's construction (Graf, 1983).

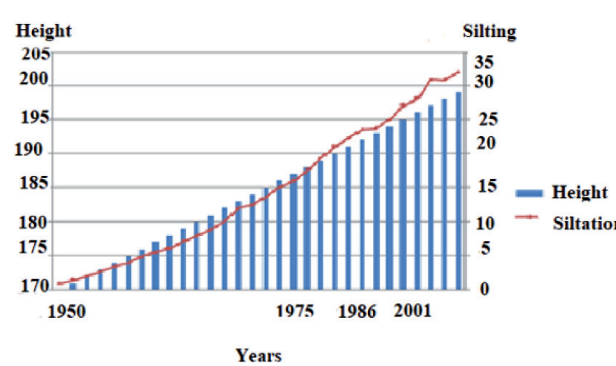

Fig. 7 - Evolution of Siltation according to altitudes

STAGE	HEIGHT (m)	SILTATION (Mm^3)	TOTAL SILTATION (Mm^3)	SILTATION RATE (%)	
	170	1			
	171	1.45			
	172	2			
	173	2.65			
	174	3.5			
	175	3.95			
	176	4.95	11.99	37.18	11.99 (18 years)
1950-1967	177	5.55			
	178	6.15			
	179	7.099			
	180	7.998			
	181	8.897			
	182	10.195			
	183	11.993			
	184	12.49			
1967-1975	185	13.61	3.087	9.64	
	186	15.08			
	187	15.97			
1975-1986	188	17.54145			11.56 (25 years)
	189	19.42	5.84	18.25	
	190	20.92			
1986-1993	191	22.3015	2.64	8.25	
	192	23.56811			
	193	23.66			
	194	25.0323			
1993-2001	195	27.054	4.49		
	196	28.05		14.03	
	197	30.8255			8.44 (17 years)
2001-2009	198	30.7612	3.95	12.34	
	198.9	32			

Tab. 5 - Siltation evolution according to altitudes

CONCLUSION

The importance of solid transport in Algeria is, often, translated by a fast filling of dam's water retentions, reducing, considerably, their storage capacity, and, consequently, their lifetime (Remini *et alii*, 1994; 1995). It is interesting to mention that the genesis and the evolution of the siltation is controlled by the erosion; this important erosion contributes to the increase of the alluvionement in particular in the period of the Autumn and Spring whose rainfall seems aggressive and irregular.

The highest rainfall values coincided with the strongest erosion and sedimentation for the years 1967, 2001, 2009 (Tab. 4). The correlations that have been made between the different parameters involved in the siltation expressed a perfect concordance

The relation between the calculated capacity and the observed capacity is interpreted by a high coefficient of determination of the order of 0.02; this value reflects the importance of the model applied in the assessment of siltation the quantities of eroded soles that arrive at the dam lake contribute to increase siltation and to minimize the usable water volume. This main result being well explained by the values observed or caculated by the model.

The increase in siltation and the decrease in residual capacity determine the importance of applying the Orth formula. It is clear that the law of Nash expresses and justifies in a very good way the validity of the model.

From this study, relative to siltation of Foum El Gherza Dam, is resulted that sediments deposit profile evolution in the basin followed an accelerated way. Observed and calculated siltation intensity is moreover, due to the extreme climatic morpho dynamic and hydrologic conditions of the basin.

Hydro-bathymetric results noticed in Foum El Gherza dam are, indeed, a physical portrait of all conditions listed above. Silting evolution in the dam since its installation in water until today has occurred in an increasing way, to reach a very advanced threshold.

Calculations made by Orth's method for dam water characterization are, moreover, justified, and they confirmed, also, the trend took by temporal evolution curve of noticed alluvia in the dam. Our objective, in this contribution, was to give an idea about the intensity of this phenomenon which was, particularly, spectacular in the North of Africa (Badraoui & Hajji, 2001; Rais & Abidi, 1989). The availability of several bathymetric surveys helps technicians to better understand the evolution of siltation and the volumes of water that can be lost and find the procedures and solutions needed to minimize siltation.

The prevention remains the most efficient way to mitigate it. The measurement of siltation in dams is an important step to understand and master its operation. This direct measurement of siltation is not always easy and attainable to the responsible of small dams and hillside lakes

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