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Discussion of "Revisiting the useful life computation of Gobindsagar (Bhakra) reservoir" by Deepa S. Koomullil, U.C. Chaube and Ashish Pandey (2015)

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This paper is about the discussion of "Revisiting the useful life computation of Gobindsagar (Bhakra) reservoir"; Deepa S. Koomullil, U.C. Chaube and Ashish Pandey (ISH Journal of Hydraulic Engineering, 23nd Sep 2015, doi: 10.1080/09715010.2015.1084600).

The term useful life of a reservoir is different from terms like design life, economic life, full life, etc. Design life for Govindsagar reservoir (called the reservoir hereafter) behind Bhakra dam was taken as 100 years for the purpose of cost-benefit analysis of the project completed in 1970 after Indus treaty was signed in 1960. As per project report, estimated full life of Bhakra dam of 226-m height was 500 years (Rangachri 2005) after which the Sutlej river bed is expected to touch the spillway crest, completely losing its gross storage of 9869 Mcum. Economic life of the reservoir is the life up to which the dam continues to serve its intended purposes of irrigation, flood control and hydro-power generation profitably – either by itself or in conjunction with other dams. Gross and dead storages of the reservoir are 9869 Mcum and 2066 Mcum, respectively. As per CBIP (1994) report, design siltation rate of the reservoir was taken as 4.29 ham/100 km^2/year for computing useful life of the reservoir at the planning stage. With above siltation rate and catchment area of 56,980 km^2, the live storage of 7803 Mcum was supposed to be completely filled up in 320 years.

On the basis of hydrological survey, CWC (1991) found the actual observed sedimentation rates of the Bhakra reservoir as follows:

Year	Sedimentation rate (Ham/100 km^2/year)	Remarks
1972	4.463	The rate of sedimentation varies over years due to varying volume of water and sediments brought by the river Sutlej from time
1979	8.731	
1981	6.071	
1983	4.960	
1985	2.399	
1987	6.523	
Average sedimentation rate (1972–1983) = 5.525 Ham/100 km^2/year		

With the above accelerated average sedimentation rate of 5.525 Ha-m/100 km^2/year, the live storage of 7803 Mcum and dead storage of 2060 Mcum are expected to be completely filled up in 248 years and 65 years, respectively, i.e. a full life of 313 years instead of 500 years as assumed at the planning stage.

At the time of planning, it was assumed that the sediments will get deposited in the allocated dead storage space only. However, incoming sediments get deposited within the live storage also from the date of impounding. As per Borland–Millar classification of reservoirs (CBIP 1980), Bhakra reservoir is of class II type (Figure 1). Actual depth wise distribution of sediments deposited in the Bhakra and some other reservoirs is shown in Figure 1 (Garde 2006). It is apparent from the figure that the full life of live storage of the reservoir, as well as its useful life (at 50% loss of live storage) are reduced considerably.

Based on observed sedimentation rate (up to 1987) of 5.66 ha-m/100 km^2/year, Lagawankar et al. (1994) predicted the percentage loss of gross storage and live storage of Bhakra as 0.32 and 0.20%, respectively, which corresponds to 312 and 500 years, respectively.

Based on observed sediment data (CBIP 1989), the following times required for loss of gross storage of Bhakra reservoir were predicted:

Loss of gross storage capacity (%)	10	25	50	75	100
Time required (years)	54	135	286	439	585

It is apparent from the above discussions that there are divergent views regarding the life of Govindsagar reservoir and the utility of Bhakra dam after the expiry of its useful life. Considering the fact that the reservoir is used for irrigation, hydro-power generation and flood control in the states of Punjab, Haryana and Rajasthan in north-west India, the present paper is an extremely important one. Based on the three criteria used by the authors for deciding useful life (given in Table 4 of the paper), the useful life of the reservoir varies from 109 to 150 (with an average of about 130 years) compared to 260 years as computed at the planning stage. This is a serious development since the actual useful life is almost half of that predicted at the planning stage. The principal cause of reduction of useful life is enhanced rate of sedimentation, perhaps due to neglect in soil conservation in the catchment area. Another important reason may be due to underestimation of bed load contribution which was assumed to be only 15% of suspended load measured from observed concentration of suspended sediment and flood flow.

Apart from Bhakra, the picture is almost the same in all the reservoirs built in India after independence. In his paper on reservoir sedimentation, Murthy (1980) compared the assumed and observed sedimentation in some major reservoirs in India as given below:

Reservoir	Sedimentation rate (in ham/100 km^2/year)		Observed rate/ assumed rate
	Assumed rate	Observed rate	
Bhakra	4.29	5.95	1.33
Shivaji Sagar	6.67	15.24	2.28
Nizamsagar	2.38	6.38	2.68
Mayurakshi	5.33	16.48	3.09
Panchet	3.33	10.48	3.15
Maratila	1.33	4.38	3.29
Tungabhadra	4.67	17.95	3.84

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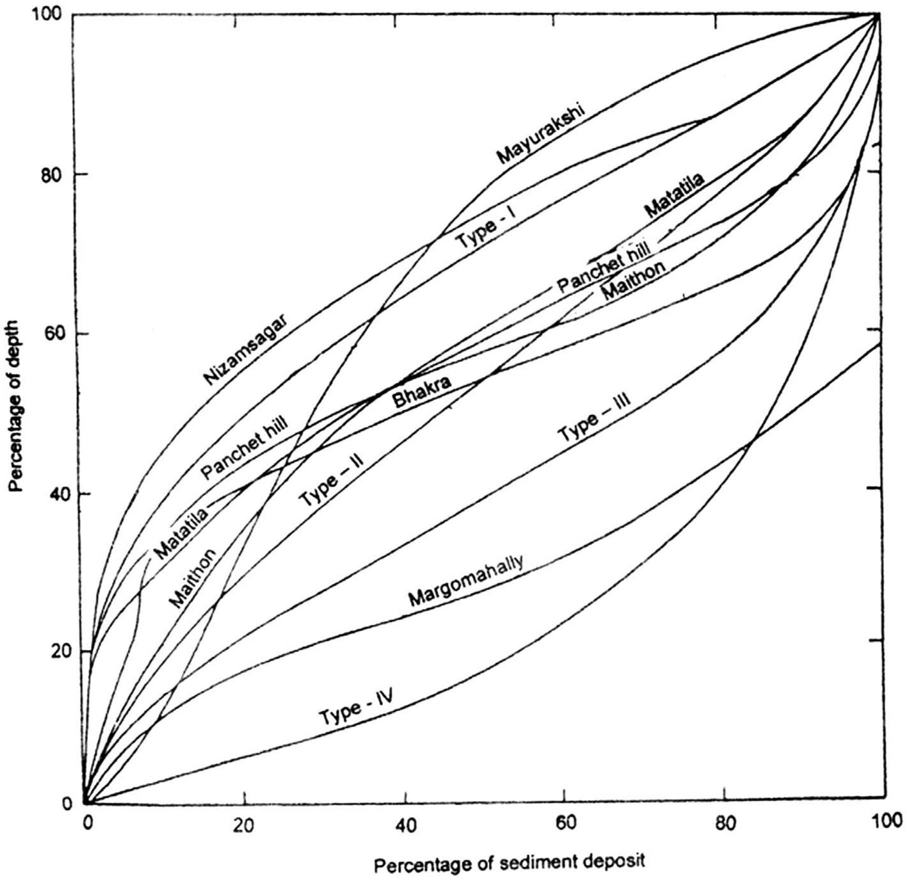

Figure 1. Showing distribution of sediments with increasing depths for different types of reservoirs and the distribution in some major reservoirs/dams in India (Including Bhakra).

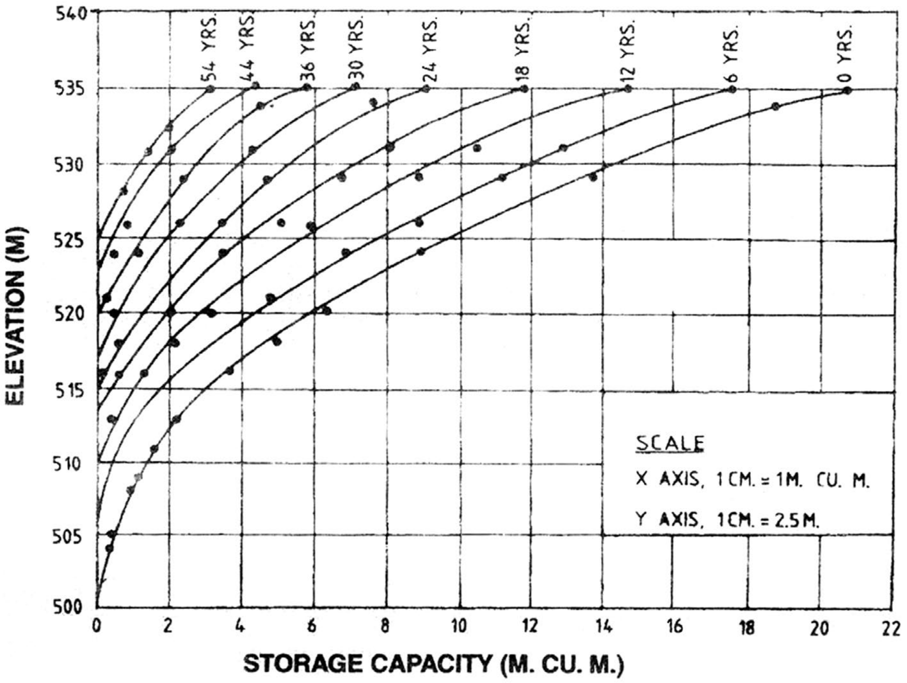

Figure 2. Showing loss in storage capacity in Kirichu dam/reservoir (in Sikim) at 6 years interval.

Discusser would, however, like to get the following clarifications from the authors:

(1) Figure 4 in the paper shows the cumulative volume of sediments deposited during 1958 to 1986 as 830 Mcum which corresponds to a sedimentation rate of 5.21 Ham/100 km^2/year. Whereas during the period 1986 to 2003, the cumulative volume of sediment deposited is 770 Ham which corresponds to sedimentation rate of 7.96 Ham/100 km^2/year. Usually, sedimentation rate decreases with time since the trap efficiency reduces with time due to

decreasing capacity of reservoir. Mazumder (2000) studied the life of a Himalayan reservoir (in Sikim province) and determined the life by area incremental method to find the loss of reservoir capacity at an interval of every 6 years (Figure 2) using Churchil's sedimentation index method (CBIP 1980). Sedimentation rate was found to be decreasing with time. Sediments trapped in storage dams built upstream of Bhakra should have reduced sedimentation rate at Bhakra. Authors are requested to explain the anomaly.

(2) Suspended sediments are usually measured by sampling in mg/l. Bed load is assumed as 10–15% of suspended load to determine the total sediment load in weight unit. Depending upon the percentage of different fractions of sediments and their unit weights, the weighted unit weight is calculated to convert total sediment load to equivalent volume in Mcum or ham in order to find the volume loss of reservoir storages. How were the unit weights of sediments computed? Apart from percentage fractions, unit weight increases with time as well as distance from dam. Did the authors take them into consideration?

(3) Under clause 2.2.2.1, authors have mentioned that Hydrological Survey and range survey method of finding bed contours are highly time consuming and laborious, whereas in remote sensing technique, there is error. Modern equipment like acoustic Doppler current profiler is very efficient and quick to obtain bed profiles in reservoirs.

(4) Did the authors consider the additional sediment load brought by river Beas after its interlinking with Sutlej river?

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