Sediment Trap Efficiency of Kodar Reservoirs: -An Experimental Study -

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Abstract:-All reservoirs are subjected to sediment inflow and deposition up to a certain extent leading to reduction in their capacity. Thus, the important practical problem related to the life of reservoir is the estimation of sedimentation quantity in the reservoirs. Large number of methods and models are available for estimation of reservoir sedimentation process. However, each model differs greatly in terms of their complexity, inputs and other requirements. In the simplest way, the fraction of sediment deposit in the reservoir can be determined through the knowledge of its trap efficiency. Trap efficiency (Te) is the proportion of the incoming sediment that is deposited or trapped in a reservoir. Most of the Te estimation methods define a relationship of the Te of the reservoir to their capacity and annual inflow, generally through curves. In this study, the empirical relationships given by Brune and Brown were used and compared for estimating the trap efficiency of Gobindsagar Reservoir (Bhakra Dam) on Satluj River in Bilaspur district of Himachal Pradesh, in the Himalayan region of India. A new set of regression equations has been developed for Brune's method and compared with Brown and other available Brune's equations. It has been found that Brune's equations developed in the present study estimated better than the other Brune's equations reported in literature. Later, in the present study it was found that Brown's approach was over estimating the Te. Hence it was again modified for Gobindsagar reservoir. It was also identified that sediments coming to this particular reservoir were mainly of coarse nature.

Key Words:- Reservoir sedimentation, Trap efficiency, Brown's method, Brune's method, Gill Method

INTRODUCTION:-

Sediments are defined as the fragmental earth materials eroded, transported and deposited elsewhere by air and water. Sediment transportation being a natural process it cannot be stopped completely. The problems of sedimentation are

1) Erosion of the place of origin
2) Transportation of sediments through river water and
3) Deposition of sediments in the reservoir which we are really interested in when it comes to the study of reservoir.

Transportation of sediment by river and their deposition in the reservoirs depend on flow conditions, type of sediments and their interaction with each other. When river water enters a reservoir, the velocity decreases because of increased cross-sectional area through which it passes. The decrease in in velocity leads to the sediment deposition sediment deposition at the bottom of the reservoir under the action of gravity. Sedimentation surveys for Indian reservoirs show that the rate of sedimentation vary from 4.75 to 14 Ha.m/100 km2/year. Most of the reservoir lose 0.5-1 % of their storage capacity to sedimentation every year. Indian Standard (IS 6158-1972) recommends a provision of 10-20 Ha.m/100 km2/year of sedimentation.

Various problems in the process of sedimentation of reservoir

1) Uncertainty of area occupied by sediment in the reservoir
2) Lack of knowledge regarding the contribution of sediment by water from the catchment.
3) Variability of sediment inflow from year to year and season to season
4) Not knowing the reservoir operation schedule
5) Varying in reservoir capacity to inflow ratio

METHODOLOGY

The available hydrological data and other information are compiled to test various models for Reservoir trap efficiency estimation and compare their relative efficiency and utility in assessing the sediment retention capacity of Reservoir. The useful lifespan of the reservoir and the possible environmental problems are also calculated and discussed.

The sediment release efficiency of a reservoir is the mass ratio of the released sediment (Vo) to the total sediment inflow (Vi) over a specified time period. It is the complement of trap efficiency (TE):

$$. TE = \frac{(Vi - Vo)}{Vi} X\ 100 \quad \text{.....[1]}$$

Release efficiency = 100 – TE .....[2]

Brune Method

Brune (1953) developed an empirical relationship for estimating long-term trap efficiency in normally impounded reservoirs based on the correlation between the capacity to inflow ratio (C/I) and applied this method to calculate trap efficiency observed in Tennessee Valley Authority reservoirs in the southeastern United States. This is probably the most widely used method for estimating the sediment retention in reservoirs, and gives reasonable results from very limited data: storage volume and average annual inflow. As a limitation, the method is applicable only to long-term average conditions. Brune noted that significant departures can occur as a result of changes in the operating rule. Brune has used the following equation:

$$TE = ((C/I)/((C/I)+(0.0025\ X\ (C/I)^2)+0.00003))) \quad \text{.....[3]}$$

Normally dry reservoirs tend to be less efficient at trapping sediment, and shallow sediment-retention basins designed for the express purpose of trapping sediment can operate much more efficiently than indicated by the curve. For instance, the All-American Canal desilting basins in Arizona would have negligible sediment trapping efficiency based on their C/I ratio, but the basins operate at a trapping efficiency of 91.7 percent. Trapping efficiency also depends on the actual storage level at which the reservoir is held during flood periods (as opposed to its nominal storage capacity), and the placement of outlets.

Brown Method

Brown (1944) developed a curve relating the ratio of reservoir capacity (C, in acre-ft) and watershed area (W, in square miles) to trap efficiency (TE in percent) and represented by the following equation:

TE =1-((1/(1+(k*(C/I)))……..[4]

TE =1-((1/(1+(k*(C/I)))…….[5]

The coefficient K ranges from 0.046 to 1.0 with a median value of 0.1.

K increases:

(1) For regions of smaller and varied retention time (calculated using the capacity-inflow ratio),

(2) As the average grain size increases, and

(3) For reservoir operations.

That prevents release of sediment through sluicing or movement of sediment toward the outlets by pool elevation regulation. Variations are mainly due to the fact that reservoirs having the same C/W ratio can have different capacity inflow ratios. Brown's curve is useful if the watershed area and reservoir capacity is the only parameters known.

Gill Method

Later, Gill (1979) developed empirical equations which provided a better fit to the three curves proposed by Brune.

Primarily for highly flocculated and coarse grained sediments:

$TE = (C/I)^{2} / (0.994701 X (C/I)^{2})+(0.006297 X (C/I))+0.3 X 10^{-5}$ …… [6]

Median curve (for medium sediments) Morris and Wiggert (1972):

TE = (C/I) / (0.012+1.02((C/I)) …….. [7]

Primarily for colloidal and dispersed fine-grained sediments:

$TE = (C/I)^{3} / ((0.1X10^{-5}-0.133X10^{3}X(C/I)+0.02621X(C/I)^{2}+1.02655X(C/I)^{3}$ …[8]

RESULT

In the present study, it was aimed to estimate the trap efficiency for Gobindsagar reservoir. The controlling agency BBMB, had conducted capacity surveys for Gobindsagar reservoir annually from 1963 to 1977 to measure the actual silt deposited. Thereafter these surveys were further being carried out on alternate years.

Table No 1. Estimation of All Sedimentation formula Year Wise

YEAR	C/I Ratio	OBSERVED TE %	ESTIMATED (TeG) % (Gill equation)	ESTIMATED Te Brown % FOR 1	ESTIMATED Te Brown % FOR 0.58	ESTIMATED Brune Te %
1983	1.04	98.98	99.92	99.8953	99.82	99.758
1984	0.72	96.5	99.66	99.89425	99.82	99.65
1985	2.19	96.53	100.24	99.89318	99.82	99.885
1986	1.05	96.57	99.93	99.8921	99.81	99.759
1987	0.69	96.6	99.62	99.89101	99.81	99.635
1988	1.03	96.63	99.92	99.88991	99.81	99.755
1989	2.66	96.67	100.29	99.8888	99.81	99.906
1990	8	96.7	100.45	99.88768	99.81	99.969
1991	2.22	96.73	100.25	99.88655	99.8	99.887
1992	0.7	96.77	99.62	99.8854	99.8	99.635
1993	2.08	96.8	100.23	99.88425	99.8	99.879
1994	0.83	96.83	99.77	99.88308	99.8	99.695
1995	0.97	96.86	99.88	99.8819	99.8	99.739
1996	0.38	96.89	98.89	99.88071	99.79	99.329
1997	1.28	96.92	100.04	99.8795	99.79	99.803
1998	1.79	96.96	100.18	99.87829	99.79	99.859
1999	1.35	96.99	100.06	99.87706	99.79	99.814
2000	2.58	97.02	100.29	99.87582	99.79	99.903
2001	2.26	97.05	100.25	99.87457	99.78	99.889
2002	3.72	97.08	100.36	99.8733	99.78	99.933
2003	0.92	97.1	99.84	99.87202	99.78	99.725
2004	1.79	97.13	100.18	99.87073	99.78	99.86
2005	0.84	97.16	99.78	99.86943	99.78	99.701
2006	1.58	97.19	100.13	99.86811	99.77	99.841
2007	0.78	97.22	99.72	99.86678	99.77	99.674

2008	2.63	97.25	100.29	99.86544	99.77	99.905
2009	0.74	97.27	99.68	99.86408	99.77	99.657
2010	0.77	97.3	99.71	99.86271	99.76	99.672
2011	0.77	97.33	99.72	99.86133	99.76	99.673
2012	0.58	97.36	99.44	99.85993	99.76	99.559
2013	0.34	97.38	98.69	99.85851	99.76	99.243
2014	0.49	97.41	99.26	99.85709	99.75	99.483
2015	0.7	97.43	99.63	99.85564	99.75	99.639
2016	0.89	97.46	99.83	99.85419	99.75	99.718
2017	0.93	97.48	99.85	99.85272	99.75	99.727

CONCLUSION

The sediment trap efficiency (Te) of kodar Reservoiron kodar nala in mahasamund district, chatisgardh state, India has been estimated using Gill method, Brown's methods by (k=1 and k=0.58) , Brune's Method. The estimated Te was compared with the measured Te as well as Gill method, Brown's methods by (k=1 and k=0.58) and Brune's Method. It was found that the trend of results closely follow the Brune's method curve which shows that the sediments in this particular reservoir are mainly coarse sediments in nature, the results were compared with solution of actual trap efficiency in year 1983, 1984, 1986, 1988, 1988, 1994, 1995, 2003, 2005, 2007, 2009, 2010, 2011and 2017. Brown's method with $\kappa = 1.0$ it was found that the trend of results closely follow in the year 1990 and Hence, the constant κ was modified to $\kappa = 0.58$ (average of the observed C/I values). The modified Brown's method ($\kappa = 0.58$) and present study regression equation have been found to be below than estimating the trap efficiency in the present study area, 1985, 1989, 1991, 1993,1997 ,1998, 1999, 2000,2001, 2002, 2004, 2006 and 2008 kodar Reservoir. It was also found that, Gill method 1987, 1992, 1996, 2012, 2013, 2014, 2015, and 2016. The major advantage of these empirical methods was to give fairly reasonable results from very limited data: storage volume, average annual inflow and catchment area. As a limitation, the methods are applicable only to long-term average conditions. In the country like India where the sediment inflow and outflow are not usually measured, these empirical approaches are the best suitable approach to estimate sediment retention. Gill method

predicted 98.69 t0o 95.31 percent, Brown's methods by (k=1 and k=0.58) predicted between 99.88 percent and 99.77 to 99.78 percent respectively , Brune method predicted 99.67 to 99.725 percent, while present study predicted 96.50 to 98.98 percent..

REFERENCES

1. Arora P. K. and Goel M. P. (1994), Estimating life of a reservoir. Proc. of Workshop on Reservoir Sedimentation, Mysore (Karnataka) May 17-19, pp. 4-11.
2. Brune G. M. (1953), Trap efficiency of reservoirs. Trans. Am. Geophysical Union, Vol. 34, No. 3, pp. 407-418.
3. Churchill M. A. 1948, Discussion of analysis and use of reservoir sedimentation data. Ed. L. C. Gottschalk, Proc. of Federal Interagency Sedimentation Conference, Denver, pp. 139-140.
4. Gill M. A. (1979), Sedimentation and useful life of reservoirs. Journal of Hydrology, Vol. 44, pp. 89-95.
5. Gupta, S.C. (1991).Chemical character of ground waters in Nagpur distr ict, Rajasthan. Indian Journal of Environmental Health, 33 (3), 341349.
6. Heinemann H. G. (1981), A new sediment trap efficiency curve for small reservoirs. Water Resources Bulletin, Vol. 17, No. 5, pp. 825-830.
7. June S. Marks. (2003). California Dreaming: Public Acceptance of Potable Water Reuse. TASA 2003 Conference, University of New England, 4–6 December 2003.
8. Martha Sinclair., Samantha Rizak. (2004). Drinking-Water Quality Management: The Australian Framework. Journal of Toxicology and Environmental Health, Part A:Current Issues, 67:20-22, 15671579.
9. Rita Hochstrat., Thomas Wintgens., Thomas Melin. (2008). Development of integrated water reuse strategies. Desalination, 218 (2008) 208–217.
10. Russell, S., Hampton. G. (2006). Challenges in understanding public responses and providing effective public consultation on water reuse. Desalination 01/2006; 187(1):215-227.
11. William Stephens., Tim Hess. (1999). Systems approaches to water management research. Agricultural Water Management, 40, 3-13.