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TRAP EFFICIENCY OF ALMATTI RESERVOIR IN KRISHNA BASIN – A CASE STUDY

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Abstract **:** In this paper an attempt has been made to study the sedimentation aspects of this reservoir and to evolve the sedimentation rates and trap efficiency of Almatti reservoir.When a dam is constructed on a river to store water, sediments transported by the water flow are also stored and reservoir capacity is gradually reduced by sediment accumulation. Prediction of sediment distribution in reservoirs is an important issue for dam designers to determine the reservoir active storage capacity, outlet sill elevation, dam stability, recreational facilities, and back water conditions. In this study, the sediment deposition in Almatti on Krishna river in Karnataka is studied . The sediment rates are worked out considering the hydrographic surveys conducted by State of Karnataka and the same are compared with the hydrometrical observations conducted by CWC at various G&D stations in Krishna river. The trap efficiency is also estimated considering the observations at the gauging stations .It is observed that the hydrographic and hydrometry observations fairly tally. The trap efficiency worked out as 84.3 % a bit different from Brunes trap efficiency median curve. The trap efficiency more or less converges to the lower envelop curve.
Keywords: Sediment load, trap efficiency,FRL,storage capacity,hydrographic surveys

I. INTRODUCTION

Sedimentation processes in reservoirs and lakes have been reported by many authors, including Mahmood [1], Hotchkiss and Parker [2], Fan and Morris [3], Sloff [4], De Cesare *et al*. [5], among others. The sedimentation process in reservoirs, caused by impounding a river, results in the increase of the cross-sections available for the flow, subsequently decreasing the flow velocity. Thus, the sediment transport capacity decreases.

This causes the deposition of sediments, the consequences of which depend on the size, shape and location of the deposits.

The forecast of sediment distribution in reservoirs may be prepared using empirical and theoretical methods. Theoretical approaches to forecasting water reservoirs' silting are mathematical methods that can be divided into analytical and numerical ones. Irrespective of the type of theoretical model used, it is necessary to calibrate or verify the results of calculations. Such opportunity is created by the field test results. Regarding empirical methods they are based on data of some reservoirs in the USA which may not be applicable to the Indian conditions. Hence it is nessary to develop trap efficiency from the observed data and to adopt the revised empirical relations to suit that particular reservoir or set of reservoirs situated in India. The actual observed sediment loads and hydrographic survey throw better light on trap efficiency and often form the basis for easy empirical methods, the use of which

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does not require much effort. The results allow for the assessment of the approximate course of the analyzed phenomenon or process.

II. LITERATURE SURVEY

The Total sediment load can be estimated from hydrometric observations and establishing the sediment discharge relations.

H.G. hlimemann[6] (1975)has estimated trap efficiency of three reservoirs based on detention time and particle size. In this theory also in direct variables causing trap efficiency are used but in the present study actual observed data is used.

G. Venkatesan and Jean poison[7](2000) have estimated the trap efficiency of small reservoirs bydeveloping theoretical models based on over flow rate and concluded that these models can be used for estimation of trap efficiency of small reservoirs. As Almatti is a major reservoir this theory is not applicable to Almatti.

Abol Fazi[8](2006) has estimated the sediment load in to the Karaj Dam using hydrometry observations of upstream and downstream and compared them with the hydrographical survey of the reservoir and concluded that the results are compatible with a regression coefficient of 0.97. These observations pertain to a reservoir in IRAn and the conclusions may not be suitable for Indian conditions. Therefore it is necessary to study the hydrometrical observations and hydrographic observations of Almatti to arrive at suitable conclusions.

The rate of sedimentation and useful reservoir life have also been estimated by Vaibhav and others[9] (2008)adopting trap efficiency approach. In this determination also actual observed data of hydrographic survey is not available.

Vaibhav Garg[10] (2009)and others have developed artificial neural network models for estimation of sediment load. The observations of hydrometry vary over time and discharge and differ very signjficantly for different discharges. Therefore this method was developed . It was stated that Hydrographic observations are costly for small reservoirs and hence it was suggested that for small reservoirs this method can be used in the absence of hydrographic surveys. As almatti reservoir is a major reservoir and hydrographic observations are available this study may not be suitable for Almatti.

Jaypak and Paul ely [11](2010)have estimated the trap efficiency by hydrological modelling system using HEC-HMS based on storm rain falls and retention periods. These studies are based on other indirect parameters effecting trap efficiency but not direct observations.

Trap efficiency was also estimated for reservoirs in tropical settings for Burdekin reservoir in Australia by Lewis.S. E.[10] (2013)from observed data and compared the same with the results from Brunes and churcils methods. In this study also the trap efficiency estimated from observed data and compared with Brunes curves.

III. METHODOLOGY FOR THE PRESENT STUDY:

Almatti reservoir is on Krishna river in Karnataka state. It is one of the biggest reservoirs in Krishna and has to contribute huge quantities of flow to the down stream states of Telengana and Andhra Pradesh. Therefore it is important to study this reservoir for sedimentation and other operational aspects so as ensure that the system down below functions satisfactorily as per the awards and the down stream demand will be met at the desired levels. The salient features of Almatti reservoir are given in Table 1.

Table 1 Salient Features of Almatti reservoir

SL.NO	Particulars	Details
1	Type of reservoir	Major

2	Purpose of reservoir	Irrigation and power
3	Year of impoundment to FRL	2003
4	Silt rate assumed for design	1.00 Acft/Sq. Mile/year
5	Catchment area	35926 Sq. Miles
6	Annual rain fall in mm	500
7	Lowest bed level	488.95 m
8	Crest level	509.016 m
9	Dead storage level(MDDL)	506.87 m
10	Sill of river sluice	495.306 m
11	FRL	519.6 m
12	MWL	519.80 m
13	Maximum water spread	181 Sq. Km
14	FRL for stage 3	524.256 m
15	Maximum water spread at 524.256	487.87 Sq. Km
16	Height of dam from lowest B.L	40.3 m
17	Design flood intensity	31007 Cumecs
18	Top width of dam	7.5 m
19	No. And size of spill way gates	26 nos of 15 *10.584 m(radial)
20	No. And size of gates in stage 3	26 no.s of 15*15.24 m(radial)

In this paper an attempt has been made to study the sedimentation aspects of this reservoir and to evolve the sedimentation rates and trap efficiency of Almatti reservoir.The total sediment loads observed at the hydrometry stations on Krishna upstream of Almatti reservoir are transferred to Almatti considering the rate of sedimentation.These are then compared with the hydrographic surveys conducted and the trap efficiency is worked out.

Suspended sediment observations at various stations of Krishna basin are being observed by CWC. Galgagi is situated just upstream of Almatti on main Krishna river. Similarly Bagalkot station is situated at the end of Ghataprabha a distributary of Krishna which joins the main Krishna just upstream of Almatti. The silt loads from these two stations are considered and the average load that is being measured at these stations is worked out. This sediment will flow to Almatti. The bed load is considered as 20 % in addition to the suspended load. The consolidated density of the sediment is considered as 1.4 t/cum. This is used to convert the sediment load in tons into sediment volume.

The basic rate of silt load i.e without any effect of reservoirs intervention is worked out from sediment observation stati ons at Krishna Agraharam , Huvanahegdi on main Krishna and yadgir on bhima stations as the catchment is not effected by the reservoirs except Jurala the trap efficiency of which is very low. This rate is then applied to the free catchment between Galgali, Bagalkot and Almatti and added to the sediment loads observed at Galgali and Bagalkot to arrive at the total sediment load flowing to Almatti reservoir.

The hydrographic survey was conducted by state of Karnataka in 2009 and these studies are used to estimate the sediment trapped in Almatti. The reservoir was completed upto crest in 1994 and filled upto MDDL+506.87. The reservoir was filled up to crest from 1998 on wards.The level of 515 is maintained in 2001,2002 and water is stored up to FRL in 2003.The reservoir is being operated with FRL +519.6 m from 2003 onwards. The revised area, capacities corresponding to the reservoir elevation are given in Table 2. The graphical representation of the elevation vs area and capacity for original and revised as per survey 2009 are given in fig.1& fig 2 respectively.

TABLE 2
Area-elevation-capacity table of Almatti reservoir(Original and 2009 survey)

elevation	original		revised(2009 survey)		
	area	capacity	area	capacity	
500	25.82	157.34	22.74	92.7	
503.5	41.31	259.6	40.31	203.03	
504	51.23	304	50.86	225.77	
504.3	54.34	318	54.31	241.54	
504.6	57.9	335	57.1	258.25	
504.9	61.2	353	59.97	275.81	
505.2	64.7	373	63.37	294.31	
505.5	68.3	394	66.65	313.81	
505.8	71.9	414	70.9	334.43	
506.1	75.7	438	75.15	356.34	
506.4	80	460	79.15	379.48	
506.7	83.06	485	82.61	403.74	
506.87	85.33	500	84.43	417.94	MDDL
507	87.33	510	86.08	429.03	
507.3	93.33	538	91.67	455.68	
507.6	97.6	567	95.76	483.79	
507.9	102.66	600	99.46	513.08	
508.2	106.8	628	103.96	543.59	
508.5	112	660	108.4	575.44	
508.8	117.33	697	113.39	608.7	
509.1	121.6	730	118.27	643.45	
509.4	126.66	768	123.12	679.66	
509.7	132	808	128.14	717.34	
510	137.33	848	133.21	756.54	
510.3	142.66	888	137.73	797.18	
510.6	148	932	142.54	839.22	
510.9	153.33	976	147.25	882.69	
511.2	160	1020	153.05	927.73	
511.5	165.33	1070	159.64	974.63	
511.8	172	1120	166.31	1023.52	
512.1	178.66	1174	172.97	1074.41	
512.4	184	1228	179.64	1127.3	
512.7	189.33	1283	186.31	1182.19	
513	194.66	1342	192.97	1239.07	
513.3	201.06	1400	199.45	1297.94	
513.6	206	1463	204.86	1358.58	
513.9	215.33	1524	211.89	1421.09	
514.2	226.66	1595	221.25	1486.05	
514.5	238	1660	233.89	1554.32	

514.8	249.33	1735	247.94	1626.58
515.1	261.33	1812	261.53	1702.99
515.4	274.66	1896	275.32	1783.51
515.7	287.33	1980	288.41	1868.06
516	301.33	2068	301.53	1956.55
516.3	316	2155	314.86	2049
516.6	329.33	2255	327.28	2145.31
516.9	344	2356	340.65	2245.49
517.2	360	2460	355.56	2349.92
517.5	375.33	2574	371.35	2458.95
517.8	390	2688	387.35	2572.74
518.1	407.33	2810	404.72	2691.54
518.4	425.33	2930	421.8	2815.51
518.7	441.33	3065	438.01	2944.48
519	457.33	3200	454.93	3078.41
519.3	476	3340	471.35	3217.35
519.6	487.87	3486	488.26	3361.28
519.9	509.37	3635	504.71	3510.22
520.2	522.66	3790	518.87	3663.75
520.5	537.33	3950	533.1	3821.55
520.8	550.66	5015	546.86	3983.54

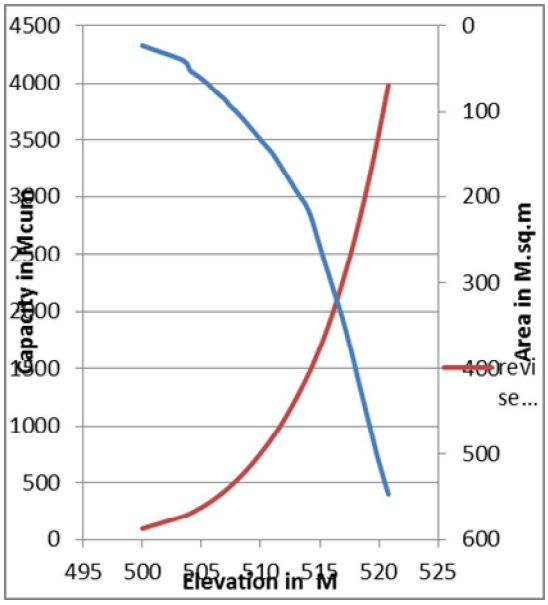

FIG1 : ELEVATION VS AREA , CAPACITY OF ALMATTI RESERVOIR(ORIGINAL)

From table 2 it could be seen that the revised capacity at FRL i.e 519.60 m is 3361.28 Mcum as against the original capacity of

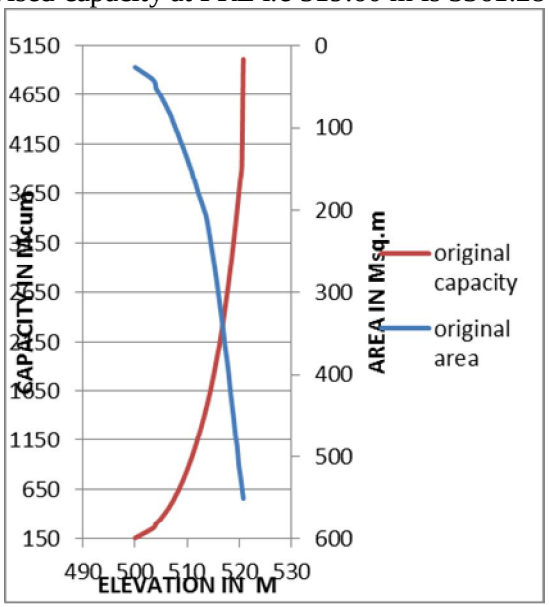

FIG2 : ELEVATION VS AREA , CAPACITY OF ALMATTI RESERVOIR(REVISED)

3486.00Mcum . Therefore the sediment trapped in Almatti reservoir for the period 1994 to 2009 is 3486-3361.28=124.72 Mcum.

The sediment volumes trapped and the total sediment loads are considered and the trap efficiency is worked out.

IV. SEDIMENT LOAD AND TRAP EFFICIENCY CALCULATIONS IN ALMATTI RESERVOIR

4.1. Total sediment load at Almatti:There are two hydrometric stations up stream of Almatti one at Galgali on main Krishna and another on Ghataprabha at BagalKot. All the sediment that flows from these measuring sites and the sediment generated in the intermediate catchment between Galgali & Bagalkot to Almatti will flow in to the Almatti reservoir. Thus the total silt load that will be deposited in Almatti on an average per year and the rate of sedimentation in to Almatti is worked out from the observed data as shown below

4.2 Sediment load from upstream gauge sites:

Average silt load @ Galgali = 4254378 Metric Tonnes (as per observed data at Galgali for 1976-77 to 1994-95)

Density adopted = 1.40 Metric Tonnes (As per CWC guidelines)

Average silt in Cum = 4254378 / 1.40 = **3038841** Cum

Silt load including bed load at 20 % = 3038841*1.20=3646609 cum

Average Silt load @ Bagalkot = 1646629 Metric Tonnes (As per observed data at Bagalkot for 1976-77 to 1994-95)

Density adopted = 1.40 Metric Tonnes/ Cum

Average silt in Cum = 1646629 / 1.40 = **1176163** CumSilt load including bed load at 20 % = 1176163*1.20 =1411396 cum

Total from two stations per year = 3646609+1411396=5058005 Cum.

4.3. **Free catchment area :**

a) Catchment area upto Almatti = 35926 sq.km.

b) Catchment area upto Galgali = 22559 sq,km

c) Catchment area upto Bagalkot = 8609 sq.km

The Catchment area between Almatti, Galgali & Bagalkot

[a-(b+c)] = 35926- 31168 = **4758** sq.km

4.4 .**Rate of siltation from un intercepted catchment :**

Rate of sedimentation from unintercepted catchment was worked out from the sediment observation stations at Krishna Agraharam , Huvanahegdi on main Krishna and yadgir on bhima stations as this catchment is not effected by the reservoirs except Jurala . The sediment that flows in to jurala is sediment loads from huvanahegdi and yadgir as well as the sediment generated from unintercepted catchment between huvanahegdi ,yadgir and jurala.Out of this silt load some portion is trapped and the rest goes down.This sediment flowing down and the sediment generated from jurala to Krishna agraharam should reach Krishna agraharam. to get the total sediment load reaching Krishna Agraharam.

The average sediment load from huvanahegdi = 12867091 MT(CWC data from 1976-1994)

The average sediment load from Yadgir = 14424770 MT(CWC data from 1976-1994)

Total load from both stations considering bed load as 20 % and density as 1.4= (12867091+14424770)*1.2/1.4=23393024 Cum

The average sediment load from Krishnaagraharam = 22697669 MT(CWC data from 1976-1994)

Total load from Krishna Araharam considering bed load as 20 % and density as 1.4=

22697669*1.2/1.4=19455145

Free Catchment area between Jurala and huvanahedgi and yadgir=129590(jurala)-55150(huvanahedgi)-69863(yadgir)=4577 sq. Km

Free catchment from jurala to Kagraharam =132920(kagraharam)- 129590=3330 Sq. Km

The trap efficiency as per Brunes curve is 45 %(lower envelope)

Let x be the basic rate. Then

(Sediment from huvahegdi and yadgir+4577*x)*0.55+3330 *x= sediment at Krishna agraharam

(23393024 +4577*x)*0.55+3330*x =19455145 Cum

Solving for x , x works out to 1126 cum/sq.km/year. This equals to 2.486 Acft/sq.mile/year

4.5. silt load from Free catchment between almatti and Galgali&Bagalkot:

The intervening catchment between Galgali, Bagalkot and Almatti= 4758 Sq. Km

Silt- load generated from free catchment = 4758 * 1126 = 5357508 Cum including bed load for one year..

4.6. Total silt load at almatti :

The total sediment load per year works out to works out to 5058005+5357508=10415513 Cum or 10.42 Mcum.

Over all Rate of silt up to Almatti= 10.42*1000000 / 35926 = **299** Cum/sq.km

(or) 0.621 acre-feet / sq. mile per year.

4.7. Sediment load by hydrographic survey:

The hydrographic survey was conducted by the state of Karnataka in 2009 in Almatti reservoir using DGPS,Digital echo sounder,total station, Auto level and various soft wares. The study indicated that the total silt deposited in Almatti at FRL of 519.6 m is 124.72 Mcum.
The impounding of Almatti started in 1994. Water was stored up to a level of 506.87 m during this year. From 1998 crest level is maintained.From 2001-02 a level of 515 was maintained for two years. Thereafter from 2003-04 on wards the FRL of 519.6 m is being maintained every year.

4.8. Trap efficiency:

The trap efficiency is worked out as below.

The silt generated per year= 10.42 Mcum

The trap efficiency adopting Brunes lower envelope curve is worked out for the period when the reservoir was not filled up to FRL and the trap efficiency after the full impoundment is worked out.
The trap efficiency at 506.87 =0.70

The trap efficiency at crest i.e at 509.016 = 0.77

The trap efficiency at 515= 0.90

10.42*0.70*4+10.42*3*0.77+10.42*0.90*2+10.42*x*6= 124.72 where x is trap efficiency of almatti after full storage upto FRL i.e 519.600 m

Solving for x we get 0.843

Therefore considering FRL of 519.6 m the trap efficiency will be 84.3 %. The rate of siltation is 8.7868 Mcum/year or 0.310 TMC per year which is less than 1 TMC/ year indicating this reservoir will satisfactorily function for its entire life as the capacity at FRL is 123 TMC. It is proposed to increase FRL to 524.256 m .Then the sediment trapped will increase

V. CONCLUSIONS&FUTURE SCOPE:

From the above calculations it could be seen that the rate of silt per year per sq. Km catchment area area up to Almatti worked out to 299 Mcum/Sq.KM/year or 0.621 Acft/sq.Mile/year. This is less than the load adopted for design of Almatti reservoir . thus the reservoir will function satisfactorily to meet its planned demands and sedimentation is not going to reduce the life of the reservoir. The total silt load per one year on an average worked out to 8.7868 Mcum or 0.31 TMC /year which when compared to the live storage of about 120 TMC indicate that the useful reservoir life will not get effected and the benefits will be available for the entire planned period and beyond.The Trap efficiency of Almatti reservoir worked out to 84.3 %. This is slightly less than the trap efficiency observed by median cyurve of Brune and indicates that it more or less converges to lower envelope curve. This trap efficiency may be adopted for Almatti foy any studies based on the total sediment load generated and measured in Krishna river. These trap efficiencies may be checked with future hydrographic surveys and analysed for any change in trap efficiency.

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