International Conference "Water, Environment, Energy and Society" (WEES–2009)
New Delhi, 12–16 January 2009

Assessment of Reservoir Sedimentation in Maharashtra

M.S. Mundhe[1] and S.K. Kalvit
Maharashtra Engineering Research Institute
Dindori Road, Nashik, Maharashtra - 422 004, INDIA
E-mail: rsgid@dataone.in

ABSTRACT: In Maharashtra, huge water storage potential is created so far by constructing several dams of major, medium and minor category. Some of these have been seriously affected by siltation, pollution, growth of water weeds reducing the water storage potential of these reservoirs. In many cases the rate of sedimentation in reservoirs is observed to be much higher than the rate considered while designing. Increasing population and growth in industrial sector as well as rapid urbanization is putting extra burden on existing water storages. It has there fore become necessary for the planner to know silt load accumulated in the reservoirs to use the present useful contents judiciously and optimally.

In this direction a review of the silt load in many reservoirs is taken in the State by conducting sediment assessment surveys of these reservoirs. **M**aharashtra **E**ngineering **R**esearch **I**nstitute, Nashik, a Research & Development wing of the State Water Resources Department, has so far conducted sediment assessment surveys of about 45–50 reservoirs. The surveys for major and medium sized water bodies were conducted using satellite remote sensing technique and DGPS based bathymetric survey and for small water bodies, conventional hydrographic surveys were conducted. These reservoirs are located in different geographical parts of the state representing different hydrological and catchment characteristics. The observed silt load in many reservoirs is found to be higher than the designed one. In general it was also observed that the silt rate is more in case of reservoirs having smaller catchment area. But at the same time, the annual percent loss in storage on an average is less than 0.3% which is not alarming one. In case of reservoirs in non ghat area of deccan plateau, the average rate of siltation is observed to be more than the design rate but is near about the rate now prevailing in the state and the annual percent loss in storage capacity is in between 0.3% to 0.5%.

INTRODUCTION

Erratic rainfall and its non uniform distribution in the state demanded more reservoirs to be constructed to store water during monsoon and utilise it throughout the year. In Maharashtra, huge water storage potential is created so far by constructing several dams of major, medium and minor category. Apart from these, many old small natural and manmade tanks are in existence, which are being used for domestic water supply to nearby villages. Some of these have become abundant over a period of time because of siltation, pollution, growth of water weeds and rapid urbanisation. Siltation in many major/medium reservoirs also affected the designed water storage potential of these reservoirs. In many cases the rate of sedimentation in reservoir is observed to be much higher than the rate considered while designing. In India every year about 5334 M Tonnes of soil (about 16.35 t/ha) is eroded annually out of which about 10% gets deposited in the reservoirs causing reduction in their storage capacity by 1% to 2% annually. Reduced storage of water on one side and increased demand on other side puts the management authorities on edge in making equitable distribution of water. Flow of silt through rivers, streams and its deposition in the reservoirs is a natural process and can not be totally stopped but can only be controlled. The sediment reduces the useful storage capacity of the reservoir. Increasing population and growth in industrial sector as well as rapid urbanisation is putting extra burden on existing water storages. It is there fore necessary for the planner to know the availability of all the surface storages and their present useful contents to use the available storages judiciously and optimally. Heavy floods every year cause more sedimentation in the reservoirs. Periodical assessment of sedimentation in reservoir has therefore attained utmost importance in all water resources development projects.

In this direction a review of the silt load in about 45–50 reservoirs has been taken in the State by conducting sediment assessment surveys of these reservoirs to know the storage lost due to sedimentation. **M**aharashtra **E**ngineering **R**esearch **I**nstitute, Nashik, a Research & Development wing of the State Water Resources Department, has the necessary infrastructure facilities like remote sensing

[1]Conference speaker

lab, DGPS based bathymetric survey unit and the conventional system for hydrographic survey and trained and experienced engineers. The sediment assessment surveys were conducted using satellite remote sensing technique and DGPS based bathymetric survey for major and medium sized water bodies and by conventional hydrographic survey for small water bodies. Each method has its own advantages and limitations. Remote sensing based storage assessment is faster and economical hence applied for reservoirs with large water spread area and located in relatively flat river basin where small change in height causes significant change in water spread viz. Jayakwadi project across river Godavari and Ujjani project across river Bhima. Both these reservoirs are amongst the three largest reservoirs in the state and located in a flat basin. Another advantage of this technique is that since satellite image (LISS III image of IRS satellite) has large ground coverage, it accommodates number of adjacent reservoirs and silt assessment studies of all these reservoirs covered in one scene become economical as the cost of the images gets distributed over the number of reservoirs. More the reservoirs covered in a single scene, lesser is the cost of the study. DGPS based bathymetric survey is more useful for valley shaped reservoirs having more storage with smaller water spread area and is being done for such reservoirs viz. Koyna Hydroelectric project Conventional hydrographic surveys are conducted for medium and small reservoirs of lesser importance. The physical survey for reservoir sedimentation assessment for small reservoirs is left to the field staff of the project authority.

GEOGRAPHY OF THE STATE

Maharashtra State is situated on the West Coast of India. The State can be divided physically in to coastal strip of Konkan and Deccan plateau. The dividing range commonly called **Sahyadri** runs almost parallel to Arabian Sea at a distance varying from 25 to 50 kms. The geographical area of the state is spread in to main three river basins viz. Tapi, Godavari and Krishna, and narrow coastal region called Konkan bounded by Sahyadri hills on one side and by Arabian Sea on the other side. Satpura hills which run almost East-West and Sahyadri hills which run North-South i.e. parallel to Arabian Sea coast are the two principal hill ranges in the State.

A large number of rivers originate from Sahyadri range and Satpura range. The rivers Krishna, Koyna, Warna, Bhima, Godavari, Mula Pravara etc are main rivers originating from Sahyadri range and flowing eastward/southeast direction. Due to its peculiar topography and high rainfall, the western Ghat area of the state covering the Sahyadri range houses large number of dams, which are relatively close to one another. The rainfall in the catchment area of these projects, which falls in the Sahyadri range, is high and contributes to high runoff in the rivers during monsoon. The Deccan plateau which covers central, south central part of the state is relatively flatter one and has a major part of the land use as a cultivable land. North Eastern part of the state is occupied by Satpura hills. The main rivers originating from Satpura range are Tapi, Wainganga, Wardha, Purna etc.

In the earlier period there was a practice to fix the dead storage level of the reservoir at a level, which has a capacity to accommodate the total silt estimated over its designed life and likely to be deposited in the reservoir based on some rational or empirical formula. It was assumed that the entire silt would be deposited below this dead storage level and there would not be any encroachment over the live storage part and the reservoir would continue to serve its planned benefits throughout its life span. But in practice, it is observed that the sedimentation takes place in the reservoir throughout its full range of depth at different rates, encroaching live storage which results in reduction of the useful storage capacity, causing an adverse impact on the planned irrigation potential, power generation and other uses.

The silt load assessment studies for total 47 reservoirs, comprising of 16 reservoirs in Krishna basin, 25 reservoirs in Godavari basin, 5 reservoirs in Tapi basin and 1 reservoir in Konkan region have been completed so far. Most of these 47 reservoirs were 20–25 years old when the first sediment assessment study was conducted. The practice of assuming silt rate of 0.75 acre-ft/sq. mile/year, which is equivalent to 3.57 Ha-m/100 sq. km/year was followed in the state till mid 70's for the design of major and medium projects. For the minor reservoirs, a silt rate of 0.35 acre-ft/sq. mile/year which is equivalent to 1.67 Ha-m/100 sq. km./year was applied. Later on based on the data of the sediment load observed at few river gauging sites in the state, average silt rate of 1.49 acre ft/sq. mile/year, equivalent to 7.5 Ha-m/100 sq. km./year is being used in the design of major and medium projects where actual data from nearby river gauging sites is not available.

Map (Figure 1) of the state on page 1647 shows the locations of reservoirs for which the sediment assessment surveys are conducted.

A basin wise list of the reservoirs for which at least one sediment assessment survey has been conducted till today is given in the Table 1 below.

Table 1: Silt Load Assessment Survey Completed so Far in the State

Sr. No.	Name of Reservoir	Name of the River Basin			
		Remote Sensing Survey			
1.	Nathsagar	–	Godavari	–	–
2.	Ujjani	Krishna	–	–	–
3.	Upper Penganga	–	Godavari	–	–
4.	Upper Wardha	–	Godavari	–	–
5.	Totla Doh	–	Godavari	–	–
6.	Bor	–	Godavari	–	–
7.	Manjara	–	Godavari	–	–
8.	Upper Vaitarna	–	–	–	Konkan
9.	Gangapur	–	Godavari	–	–
10.	Karanjwan	–	Godavari	–	–
11.	Ozarkhed	–	Godsavari	–	–
12.	Darna	–	Godavari	–	–
13.	Bhandardara	–	Godavari	–	–
14.	Kadava	–	Godavari	–	–
15.	Dhom	Krishna	–	–	
16.	Kanher	Krishna	–	–	–
17.	Panshet	Krishna	–	–	–
18.	Veer	Krishna	–	–	–
19.	Majalgaon	–	Godavari	–	–
20.	Lower Terna	–	Godavari	–	–
21.	Varasgaon	Krishna	–	–	–
22.	Dham	–	Godavari	–	–
23.	Lower Wunna	–	Godavari	–	–
24.	Chanakapur	–	–	Tapi	–
25.	Waghad	–	Godavari	–	–
26.	Koyna	Krishna	–	–	–
27.	Bhatgar	Krishna	–	–	
	Total for basin	8	17	1	1
	Hydrographic survey				
1.	Koyna	Krishna	–	–	–
2.	Yeldari	–	Godavari	–	–
3.	Ramtek	–	Godavari	–	–
4.	Girna	–	–	Tapi	–
5.	Gangapur	–	Godavari	–	–
6.	Manar	–	Godavari	–	–
7.	Ekrukh	Krishna	–	–	–
8.	Asolamendha	–	Godavari	–	–
9.	Mhaswad	Krishna	–	–	–
10.	Nalganga	–	–	Tapi	–
11.	Visapur	Krishna	–	–	–
12.	Mangi	Krishna	–	–	–
13.	Tiru	–	Godavari	–	–
14.	Wan	–	–	Tapi	–
15.	Khasapur	Krishna	–	–	–
16.	Nazare	Krishna	–	–	–
17.	Bendsura	–	Godavari	–	–
18.	Khelna	–	Godavari	–	–
19.	Mukti	–	–	Tapi	–
20.	Kolgaon	Krishna	–	–	–
	Total for basin	8	8	4	–

The studies currently under progress at MERI, Nashik are listed in Table 2.

Table 2: Silt Load Assessment Studies under Progress

Sr. No.	*Name of Reservoir*	*Name of the River Basin*			
Remote Sensing Survey					
1.	Pench Hydro Proj	–	Godavari	–	–
2.	Pench Irri. Project	–	Godavari	–	–
3.	Itiadoh	–	Godavari	–	–
4.	Lower Wunna	–	Godavari	–	–
5.	Katepurna	–	–	Tapi	–
6.	Adan	–	Godavari	–	–
7.	Arunavati	–	Godavari	–	–
8.	Upper Pus	–	Godavari	–	–
9.	Lower Pus	–	Godavari	–	–
10.	Nand	–	Godavari	–	–
11.	Khindsi	–	Godsavari	–	–
12.	Yeldari (Repeat)	–	Godavari	–	–
13.	Siddheshwar	–	Godavari	–	–
14.	Bhatsa	–	–	–	Konkan
	Total for basin	–	12	1	1
Hydrographic Survey					
1.	Ghod	Krishna	–	–	–
2.	Manikdoh	Krishna	–	–	–
3.	Yedgaon	Krishna	–	–	–
4.	Hatnur	–	–	Tapi	–
5.	Kadava	–	Godavari	–	–
	Total for basin	3	1	1	

The studies of silt load assessment done so far have indicated that the actual observed silt load in many reservoirs is much higher than that considered in the design.

REGION WISE SEDIMENTATION RATES IN INDIA

The analysis of capacity survey data of 144 reservoirs throughout the country shows a wide variation in sedimentation rate of reservoirs. The sedimentation rate varies with hydrometeorology, physiography, and climate and considering these factors the whole country is classified in to 7 regions. The region wise sedimentation rate is as given in Table 3.

Table 4 shows the average observed silt load in the various reservoirs located in Ghat and Non Ghat type catchment under the three main river basins and in Konkan region of the state.

Table 5 enclosed at the end of the text, shows reservoir wise details of the study along with the results of the studies.

Table 3: showing Region Wise Sedimentation Rates

Region	*No. of Reservoirs*	*Median Value of Rate of Siltation in Ha-m/100 km^2/year*
Himalayan Region	5	21.10
Indo Gangestic plain	9	8.9
East flowing rivers up to Godavari excluding Ganga	1	6.35
Deccan Peninsular East flowing rivers	62	4.65
West flowing rivers up to Narmada	45	8.4
Narmada and Tapi Basin	3	7.5
West flowing rivers beyond Tapi and south Indian rivers	19	17.9

Table 4: Showing Average Silt Load Basin Wise

River Basin with Catchment Type	*No. of Reservoirs*	*Avg Value of Rate of Siltation in Ha-m/100 km^2/year*
Krishna		
Ghat area/Hilly area	5	11.2
Non Ghat area	10	12.3
Godavari		
Ghat Area/Hilly area	9	6.3
Non-Ghat Area	16	7.45
Tapi		
Ghat Area/Hilly area	2	6.97
Non-Ghat Area	2	5.6
Konkan		
Ghat Area/Hilly area	1	meager

Table 5: Sedimentation Studies of Major and Medium Reservoirs, Done at M.E.R.I., Nashik by Remote Sensing, Dgps Hydrographic Survey and Conventional Hydrogrphic Survey

Sr. No.	Name of Reservoir	District	Basin/ Subbasin	C'ment Area sq.km	Gross Storage Mm^3	Live Storage Mm^3	Dead Storage Mm^3	Year of First Impou Ding	Design Rate of Siltation Ha-m/ 100 sq.km per year	Year of Siltation Survey	Siltation Period	Observed Rate of Siltation Ha-m/ 100 sq.km per year
1	2	3	4	5	6	7	8	9	10	11	12	13
By Remote Sensing Method												
1.	Jayakwadi	A'bad	Godavari	21750	2909	2171	738	1975	3.57	94–97	20	10.11
2.	Karanjwan	Nashik	Godavari	248	176	166	10	1974	3.57	2001–03	28	20.34
3.	Gangapur	Nashik	Godavari	357.4	212.51	200.51	12	1965	3.57	2002–03	37	11.48
4.	Darna	Nashik	Godavari	404	202	200.61	1.39	1916	2.06	2001–03	86	3.22
5.	Majalgaon	Beed	Godavari	3840	454	312	142	1987	3.57	2000–02	14	4.31
6.	Ozarkhed	Nashik	Godavari	182	69.91	61	8.91	1984	3.57	2002–03	18	negligible
7.	Bhandardara	A'nagar	Godavari	121.73	313	304	9	1926	n.a.	2002–03	77	negligible
8.	Waghad	Nashik	Godavari	119	76	72	4	1979	n.a.	2002–03	23	7.4
9.	Lower Terna	O'bad	Godavari	1787	160	114	46	1989	3.57	2002–03	13	16.25
10.	Manjara	Beed	Godavari	2373	251	173	78	1982	3.57	2000–02	20	4.84
11.	Koyna	Satara	Krishna	891.8	2797.45	2677.7	119.8	1961	n.a.	99–2000	39	negligible
12.	Ujjani	Solapur	Krishna	14856	3320	1517	1803	1977	3.57	99–2001	24	11.35
13.	Dhom	Satara	Krishna	217.5	382	331	51	1977	3.57	99–2000	23	13.6
14.	Kanher	Satara	Krishna	204.56	286	272	14	1984	3.57	99–2000	16	11.2
15.	Veer	Pune	Krishna	1756	279	266	13	1965	3.57	99–2000	35	33.1
16.	Panshet	Pune	Krishna	120.3	303	294	9	1970	3.57	99–2000	30	33.2
17.	Bhatghar	Pune	Krishna	331.5	673	673	0	1925	n.a.	99–2000	75	38.3
18.	Varasgaon	Pune	Krishna	130	374	362	12	1992	3.57	99–2000	8	negligible
19.	Upper Wardha	Amravati	Godavari	4302	786	615	171	1990	3.57	2002–03	12	4.26
20.	Bor	Wardha	Godavari	380.75	139	127	12	1965	n.a.	2002–03	37	3.15
22.	Totla Doh	Nagpur	Godavari	4273	1241	1091	150	1980	3.57	2002–03	22	4.46
23.	Vaitarna	Nashik	Konkan	160.8	353.96	331.31	22.65	1976	n.a.	2001–03	28	negligible

By Hydrographic Survey												
Sr. No.	Name of Reservoir	District	Basin/ Subbasin	C'ment area sq. km	Gross Storage mm^3	Live Storage mm^3	Dead Storage mm^3	Year of First Impou Ding	Design Rate of Siltation Ha-m/ 100 sq.km per year	Year of Siltation Survey	Siltation Period	Observed Rate of Siltation Ha-m/ 100 sq.km per year
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Yeldari	Parbhani	Godavari	7362	934.45	809.78	124.67	1963	3.57	1983	20	5.77
2.	Ramtek	Nagpur	Godavari	212.35	117.18	114.94	2.24	1914	2.06	1987	73	9.65
3.	Girna	Nashik	Tapi	4729	608.81	523.85	84.95	1965	1.8	1978	13	8.03
4.	Manar	Nanded	Godavari	1585	138.35	111.82	26.53	1969	n.a.	1999	30	3.939
28.	Ekruk.	Solapur	Krishna	412	94.3	89.5	4.76	1871	1.54	1991	120	5.35
29.	Asolamenda	Chandrapur	Godavari	246	92.96	74.62	18.34	1918	9.94	1994	76	16.03
30.	Mhasvad	Satara	Krishna	1243	86.94	70.52	16.42	1888	1.76	1990	102	3.56
31.	Nalganga	Buldhana	Tapi	315.98	76.2	72.4	3.8	1963	n.a.	1985	22	6.24
32.	Visapur	A'nagar	Krishna	412	42.76	33.3	9.45	1902	n.a.	1988	86	8.35
33.	Mangi	Solapur	Krishna	304	33.8	32.7	1.1	1957	n.a.	1995	38	2.97
34.	Tiru	Latur	Godavari	269.67	23.32	15.3	8.02	1976	3.96	2000	24	7.7
35.	Wan	Buldhana	Tapi	278.94	83.46	81.96	1.5	1988	n.a.	2001	13	7.85
36.	Khasapur	O'bad	Krishna	564.2	19.82	15.8	3.97	1954	1.2	1996	42	2.72
37.	Nazare	Pune	Krishna	397.82	16.17	10.48	5.68	1974	2.38	1986	12	3.2
38.	Bendsura	Beed	Godavari	188.42	13.12	9.7	3.42	1955	3.02	1995	40	6.96
39.	Khelna	A'bad	Godavari	161.6	12.61	11.08	1.53	1964	1.26	1985	21	2.07
40.	Mukti	Dhule	Tapi	88.6	9.68	9.64	0.04	1893	n.a.	1991	98	3.16

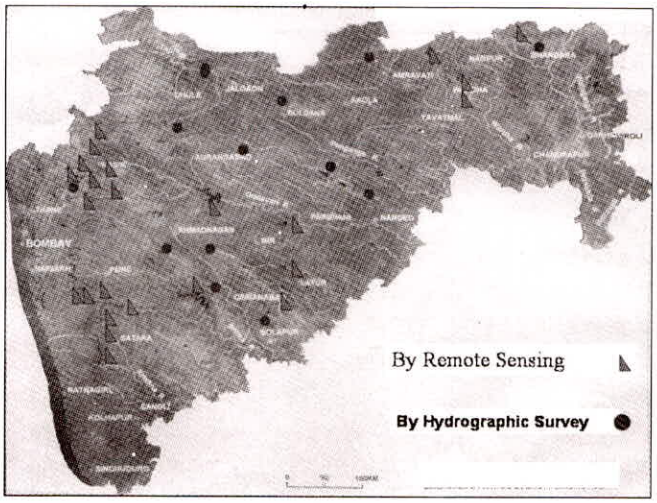

Fig. 1: Maharashtra Map

From the studies conducted by different agencies for different reservoirs in the nation and abroad it has been observed that actual sediment load in the reservoirs in the first few years after impounding is higher in the initial period but gets stabilized subsequently in the later period. This fact, however, could not be supported for reservoirs in the state in absence of periodical repeat surveys.

FINDINGS OF THE WORK

The designed rate of sedimentation in case of large number of reservoirs constructed so far was either 3.57 Ha m/100 sq. km/year or less than this. But there is a wide range of variation in the observed rate of sedimentation. The rate of siltation ranges between 2 ham/100 sq. km/year to 38 ham/100 sq. km/year. The general finding is that the the siltation rate is more when the catchment area is less. This is probably because of the silt from the catchment is directly draining in to the reservoir. For smaller catchment the chances of silt getting deposited in the river course are less unless the river slope is flat. In case of reservoirs studied so far most of the reservoirs situated in the western ghat have small catchments ranging from 120 sq. km. to 500 sq. km. only. Though the siltation rate seems to be higher for these reservoirs, the other important parameter viz. percentage of capacity loss per year is less. In case of many reservoirs located in the non Ghat area in the deccan plateau, the average siltation rate is near to 7.5 ha m/100 sq. km/year. But the percentage of annual loss in capacity is more. Most of the reservoirs in the non ghat area have relatively larger catchment size.

CONCLUSIONS

The available data of sediment load after surveys conducted so far indicates that there is a wide range in the variation of sediment load in the reservoirs. But the general finding is that the rate is higher for the smaller catchment. But the volumetric silt content is less in case of the reservoirs in the western ghat area. The trend is just reverse in case of reservoirs in deccan plateau. The reservoirs here have a larger catchment and lower silt rate. But the volumetric silt content in the reservoir is more. A large data base of silt load from different parts of the state would be useful to prepare the sediment map of the state showing Iso – Sediment lines.

REFERENCES

Compendium on silting of reservoirs in India a CBIP Publication.

Dams in Maharashtra, A WALMI Aurangabad Publication - 2000.

Technical reports on siltation study of reservoirs in Maharashtra, conducted by MERI, Nashik.