Reservoir Siltation in India: Latest Studies

Revealing Results, a Wake up Call

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Most parts of India being dependent for water on 3-4 month long monsoon, Reservoirs are created to store water for use in non monsoon months. The reservoirs, created by dams on rivers, also get silt in the water of the rivers that enters the reservoirs and a significant proportion of the silt settles down in the reservoir, thus reducing the space available for storage of water. Moreover, studies over the years have shown that the silt gets deposited in both the dead storage (the storage at the bottom, below the Minimum Draw Down Level, which is not used under normal circumstances) and in the Live Storage (LS). This process of accumulation of silt in the reservoirs is called siltation. Siltation results in reduction in benefits from the projects constructed at huge costs to the nation. Siltation of reservoirs can also have a number of other impacts, including increased evaporation losses, increased backwater flooding and also could damage the power house turbines.

Gregory Morris, (author of Reservoir Sedimentation Handbook, 1997) in a paper presented at the Sixth International Symposium on River Sedimentation in New Delhi in 1995 wrote, "Planned Obsolescence due to sedimentation affects most reservoirs worldwide, not just in India, and will render many of them unusable in the foreseeable future… Dams are uniquely different from engineering infrastructure such as roads, harbors, and cities, and which can be reconstructed on the same site occupied by obsolete infrastructure. Dams cannot be reconstructed at the same site once the reservoir has filled with sediment; the sediment must either be removed or the site abandoned. The cost of sediment removal at a large reservoir can easily exceed the original dam construction cost by an order of magnitude."

India has by now about 4500 large reservoirs[1] and lakhs of smaller reservoirs. Periodical capacity surveys of reservoir help in assessing the rate of siltation and reduction in storage capacity. This information is necessary for efficient management of the reservoir. Periodical capacity survey of reservoirs in a basin is also necessary to arrive at a realistic siltation index for planning of future reservoir projects in the basin.

We recently obtained siltation studies of 27 reservoirs in India from the Central Water Commission (CWC), the technical arm of the Govt of India's Ministry of Water Resources, under the Right to Information Act. These studies were done through Satellite Remote Sensing (SRS) technology, but they also give information about the findings of previous siltation studies for the respective reservoir done through the more traditional hydrographic method. Some of the major findings from these studies are given below.

The Big Picture Broadly, the quality of SRS survey reports leave a lot to be desired. The reports from CWC are worse compared with those from the Regional Remote Sensing Service Centre (RRSSC), Jodhpur. In most cases, the actual rate of siltation is found to be higher than the design rate. For the 23 reservoirs (excluding the four reservoirs from the 27 SRS reports for which the SRS surveys give LS greater than the original surveys), the annual loss in live storage capacity is 214.2 MCM, that is 0.912% of the original live storage capacity. These 23 reservoirs have already lost 23.11 % of LS by 2006. The distribution of reservoirs with respect to proportion of original LS lost through siltation is as follows.

Lost capacity, as % of LS	**> 40%**	**25-40%**	**20-25%**	**15-20%**	**10-15%**	**5-10%**	**<5%**
Number of Reservoirs	2	3	3	5	4	2	4

Considering that we now have about 214 BCM of live storage capacity through large reservoirs and if we apply the same loss rate (since the reservoirs in this sample are well distributed geographically and represent both small and large and also low and high siltation rate reservoirs, we may not be too much off the mark), we are losing about 1.95 BCM capacity annually. This shows that the annual loss figure of 1.3 BCM arrived at by the Govt of India's National Commission for Integrated Water Resources Development may prove to be an underestimate.

This should alarm everyone, for what this means is that firstly, we have already lost about a quarter of the LS capacity of the 23 reservoirs studied here, due to siltation. The proportion of capacity lost from reservoirs all over India would be similarly order of magnitude. This has huge implications as this means significant reduction in benefits from the reservoirs in terms of hydropower generation, irrigation, water supply and flood management. In economic terms, creation of 1.95 BCM of capacity would at today's costs would require at least Rs 2017 crores. This means that we are daily losing reservoir capacity worth Rs 5.53 crores.

[1] Large reservoirs as created by Large Dams, a Large dam is defined (by the World Commission on Dams, www.dams.org) as one having height over 15 m from the deepest foundation level.

Reservoir Capacity Loss (Live Storage)

Name of reservoir	Year of impounding	Original LS (MCM)	Reassessed LS capacity through SRS/ earlier surveys		Capacity loss (MCM)	Span	% Loss	Annual % loss	Siltation rate MCM/ yr	Capacity loss anticipated till 2006	
			Year	MCM						MCM	%
Bhadar	1964	223.703	2000	187.79	35.913	36	16.05	0.446	0.998	41.916	18.713
Damanganga	1983	502	1999	464.46	37.54	16	7.48	0.4675	2.35	54.05	10.7525
Gumti	1984	312.9	2003	249.07	63.83	19	20.40	1.074	3.36	73.91	23.62
Halali	1976	226.940	2003	188.583	38.357	27	16.91	0.626	1.42	42.62	18.78
Isapur	1983	928.262	2003	899.629	28.633	20	3.08	0.154	1.43	32.92	3.55
Kadana	1983	1712	1994	1491.71	220.29	11	12.87	1.17	20.03	460.65	26.91
Kallada	1985	423.953	2003	376.705	47.248	18	11.14	0.62	2.62	55.13	13.00
Krishnarajasagar	1932	1275.70	2000	1215.94	59.76	68	4.68	0.068	0.88	61.96	4.84
Kyrdemkulai	1983	3.824	2002	3.414	0.410	19	10.72	0.56	0.02	00.49	12.81
Lower Bhawani	1955	780.546	2000	702.025	78.521	45	10.06	0.224	1.74	89.01	11.40
Maithon	1955	607.268	2001	453.69	153.578	46	25.29	0.549	3.34	170.25	28.04
Matatila	1956	1132.7	1999	702.33	430.37	43	38.00	0.884	10.01	500.43	44.18
Mayurakshi	1955	547.59	2000	474.82	72.77	45	13.29	0.295	1.617	82.47	15.045
Narayanpur	1982	867.889	1997	740.345	127.544	15	14.70	0.98	8.50	204.07	23.52
Palitana	1959	374.832	1996	304.226	70.606	37	18.84	0.509	1.908	89.69	23.923
Panam	1977	689.567	2003	660.993	28.574	26	4.14	0.16	1.09	31.88	4.62
Parbati	1963	102.893	2003	86.405	16.488	40	16.02	0.40	0.41	17.72	17.22
Ramsagar	1905	29.397	2003	24.663	4.734	98	16.10	0.165	0.05	04.88	16.60
Ranapratap Sagar	1970	1861.36	2002	1720.13	141.23	26	7.59	0.237	4.41	158.88	8.532
Rengali	1983	3412	2001	3217.74	194.26	18	5.69	0.32	10.79	248.85	7.29
Sondur	1988	179.611	2003	134.788	44.823	15	24.95	1.66	2.99	53.77	29.94
Srisailam	1984	7165.83	1999	5152.50	2013.33	15	28.10	1.87	134.22	2952.84	41.21
Umiam	1965	131.70	2002	130.124	1.576	37	1.19	0.03	0.04	1.73	1.31
TOTAL (23)		**23492.465**		**19582.08**	**3910.385**		**16.65**	**0.912**	**214.223**	**5430.116**	**23.11**

Remarks Four reservoirs (Jakham, Idukki, Machhkund and Dudhwa not included here as their live storage capacity was found to have gone up following SRS survey and the original surveys were grossly in error. For five reservoirs (Bhadar, Damanganga, Mayurakshi, Naryayanpur and Palitana) we have taken the siltation rate from the previous hydrographic survey as SRS survey discovered that the LS capacity has increased from the previous hydrographic survey, but there were sufficient reasons for deficiencies in the SRS survey. For Ranapratap Sagar Reservoir, we have assumed that siltation rate was same for 1970-1996 as that for 1996-2002. In case of Matatila reservoir, we have taken the loss from 1956 gross (only loss in gross capacity is given in the SRS survey for 1999) capacity and not 1962 gross capacity as recommended by the SRS report as the reasons put forwarded by SRS survey were not convincing enough. Srisailam: Reservoir was built in 1984. SRS survey says that the original survey of 1990 wrong. However, the 1990 survey being of doubtful accuracy, we have used the 1984 and 1999 survey results.

The trend That siltation is a serious issue and action is required to arrest the destruction of productive reservoir capacity created at such huge costs has been known for many years. Morris, in his paper in 1995 cited earlier had said, "the overall picture indicates that reservoir sedimentation is a serious national problem which requires immediate action…"

The Mid Term Appraisal of the 9th Plan had also warned (Oct 2000, p 76), "there is an urgent need to review the status of reservoir sedimentation." However, most such warnings have gone unheeded and catchment area treatment that can help reduce the siltation, has largely remained non existent, except on paper.

The Report of the Govt of India's National Commission of Integrated Water Resources Development implies that we are losing about 1.3 BCM of storage capacity each year. That should be alarming enough for everyone as at today's rates creation of 1.3 BCM storage capacity would cost Rs 1448 crores. That means that on an average, each day we are losing Rs 4 crores worth of storage capacity through siltation.

Heavily silted reservoirs As revealed by the SRS studies, some of the heavily silted reservoirs of India are listed below.

⇒ **Matatila** 38% gross capacity lost between 1956 and 1998-9. The dead storage up to the original Minimum Draw Down Level (MDDL) of 295.66 m is completely filled with silt. Even further level upto 296.15 m is now completely filled with silt. Total capacity loss by 1999 = 430.47 MCM (million cubic meters).

⇒ **Gumti** (Tripura): Lost 63.83 MCM, that is 20.4% live storage capacity in 19 years.

⇒ **Maithon** 25.29% Live Storage Capacity silted up in 46 years.

⇒ **Kadana** 12.85% LS capacity (278.6 MCM) silted up in 11 years.

⇒ **Srisailam** 2013.33 MCM or 28.096% live storage capacity lost in 15 years.

High Siltation Rates In case of at least 14 of the 23 reservoirs, the actual siltation rate was found to be higher than the design siltation rate, as given in table below. The comparison was not possible in a number of other cases as the design rate is not given in the SRS reports.

Actual Vs Design Siltation Rates

Reservoir	River	Design rate, mm/year	Actual rate, mm/year	Actual rate as % of design rate
Gumti (Tripura)	Gumti	0.362	9.94	2746
Kyredemkulai (Meghalaya)	Umtru	0.138	0.144	104.35
Halali (MP)	Betwa	0.476	2.032	427
Matatila (UP)	Betwa	0.132	0.370	280.3
Parbati (Rajasthan)	Parbati (Chambal)	0.157	0.524	333.8
Ramsagar (Rajasthan)	Bamani (Chambal)	0.081	0.274	338.3
Kadana (Gujarat)	Mahi	0.13	1.146	881.5
Panam (Gujarat)	Mahi	0.357	0.475	133.1
Isapur (Mah)	Penganga (Goadavari)	0.357	0.379	106.2
Mayurakshi (Jharkhand)	Mayurakshi	0.364	0.696	191.2
Maithon (Jharkhand)	Damodar	0.905	1.282	141.7
Sondur (Chhattisgarh)	Mahanadi	0.357	5.768	1615.7
Rengali (Orissa)	Brahmani	0.39	0.427	109.5
Kallada (Kerala)	Kallada	1.45	4.78	330
From Other studies				
Ukai (Gujarat-1992)	Tapi	0.149	0.814	546.3

Note: Most design siltation rates are given for gross storage, while the actual rates above are for live storages.

Tungabhadra (Siltation rate 1.01 mm/year), Panchet Hill (1.05 mm/year), Pong (2.785 mm/year), Ramganga (2.294 mm/year) and Koyna (1.52 mm/year) are some other dams with high siltation rate.

Some absurd results from SRS studies We found that in case of a number of reservoirs, the SRS studies gave absurd results as described below.

⇒ **Dudhawa** (Dhamtari dist, Chhattisgarh, Mahanadi) LS in year of impoundment[2] 1964: 284.13 MCM, goes up to 284.806 MCM in 2003. This is an absurd result as the Sondur reservoir in the nearby area has in the meantime lost substantial capacity.

[2] Impoundment means filling of reservoir.

⇒ **Idukki** (Kerala): LS in year of impoundment 1974: 1461.81 MCM goes up 2003 to 1464.385 MCM. The 2003 survey estimates that the submergence area at MDDL is 23.72% higher than that in original survey and the submergence area at FRL (Full Reservoir Level) is 13.38% lower than the original survey. If we go by what the SRS study says, the LS capacity and the submergence areas in the project plans were all wrong. Moreover, even though the submergence area at FRL is lower, the capacity goes up! This shows how wrong the project plans were. The SRS study says the original survey and also the hydrographic survey done in 1999 by RITES (it found LS capacity at 1454.68 MCM) are wrong. Will there be any action against those that were responsible for these wrong surveys?

⇒ **Krishnarajsagar** The finding of the SRS study claims that the siltation is only to the extent of 59.76 MCM after a period of 68 years, i.e. just 0.88 MCM per year, is at variance with a CBIP (Central Board of Irrigation and Power) report (quoted in *Large Dams in India*, IIPA, 2002) that said that "occurrences of inordinate levels of sedimentation were also recorded for the Krishnarajsagar Dam in Karnataka. As late as 1992 catchment area treatment was recommended". The SRS study has a lot to explain, it seems. What is shocking is that the SRS study done by the CWC says (p 13), "As per the available information, no hydrographic study or sedimentation study for Krishnarajsagar Reservoir has been conducted so far". This is complete lie and CWC should know about the CBIP study findings, both being govt of India organisations.

Years of negligence The Remote Sending Directorate has stated that since 1958, when it was established that the live storage capacity of the reservoirs is getting reduced due to siltation, a systematic effort has been made by various departments/ organisations to evaluate the capacity of reservoirs. The studies under review shows how unjustified is the claim. Only in Matatila and Maithon reservoir, more than five surveys have been done. In case of Palitana three surveys has been done. Three reservoirs have been reassessed twice and six reservoir only once. Rest 15 reservoirs have been assessed for the first time through remote sensing survey recently. Ramsagar, Krishnarajasagar, Lower Bhawani, Dudhawa, Umiam - all these old reservoirs have been assessed for the first time, as stated in the studies. Ramsagar reservoir in Rajasthan constructed in 1905 has reassessed for the first time in 2003.

THE DAM BLUNDERS Reading the SRS reports, we found what serious blunders our dam planners are capable of. Here we are giving some of the big blunders of our dam planners, exposed by these reports.

⇒ **Jakham** The SRS study says that the LS in 2002 was found to be 32.64% *higher* that the planned live storage area of 132.28 MCM, the first impoundment was in 1986. The submergence area at FRL is even higher at 14.923 km^2, 47.75% higher than the planned figure of 10.1 km^2. The recalculated water spread area at the time of impoundment comes to 16.218 km^2, which means the submergence area in 1986 was 60.57% higher than the planned figure. In other words, the project authorities submerged an additional 6118 ha of land, what happened to the people in this submergence zone is not known. The SRS study says (P 32) makes a shocking admission for these gross errors, "The results of Jakham reservoir were discussed with many officials of the irrigation department. They were of the opinion that there might be some error in conversion of area values from one unit to another." Can one entrust planning, construction and operation of large dams in the hands of officials who can present such excuse for the gross errors in reservoir designs? Will there be any consequences for these gross blunders?

⇒ **Matatila** According to the SRS study, the original surveys were inadequate: "Because of the capacity of the project purpose was estimated earlier in 1956 on the basis of inadequate survey, the gross capacity of 985.71 MCM has been taken as basis."

⇒ **Idukki** According to the SRS study, the original LS and submergence area of the reservoir were wrong.

⇒ **Isapur** The original Live storage and gross storage capacity of the project were found to be wrong. The SRS study says (P 15) "After a few years of Reservoir Operation it came to notice of authorities that there are certain discrepancies in the original stage-area-capacity table. The original values and survey details were submitted to the Central Design Organisation, Pune. Project authorities & CDO officials found out that there are certain calculation discrepancies in the original table. The values were recalculated & new gross and live storage were fixed at 1241.537 and 928.262 MCM respectively." This meant a reduction of 37.523 MCM in gross storage capacity and a reduction of 35.837 MCM in live storage capacity.

⇒ **Machhkund** Original LS capacity (1955): 892.55 MCM increased to 954.23 MCM under SRS study. As stated in the SRS study, the original survey is wrong. The original gross storage capacity also seems to be wrong.

⇒ **Rana Pratap Sagar** The SRS study concludes, "In view of the above findings it may be concluded that the results of earlier surveys of 1970 and 1996 (CES) are incorrect." This innocuous sounding statement is supposed to imply that the live storage and gross storage capacities of the project as planned were wrong, possibly some other parameters could also be wrong. Will there be any action against those responsible for the wrong surveys of 1970 and 1996?

⇒ **Srisailam** The SRS report concludes (p 41) that the correctness of the original survey is doubtful. Thus the actual original live storage capacity of the reservoir, if we go by SRS conclusion, must have been substantially lower (the reduction likely to be in excess of 1.5 BCM) than the figure of 7165.83 MCM used in the plans.

Quality of Reports Some of the more important problems found in the report are listed here. These only reflect how poor is the quality of the reports.

⇒ The Kadana SRS study says (p 6) the reservoir was impounded in 1983, when in reality the impoundment happened in 1977 (according to the CBIP and CWC sources quoted in *Large Dams in India* and also according to a paper presented at 1995 International Symposium by scientists from Gujarat Engineering Research Institute). Moreover, both these sources also say that there have been hydrographic surveys in the past, but the SRS study does not have any information about the same.

⇒ The Lower Bhawani SRS study says (p 7) that no previous hydrographic surveys have been done, which is a complete lie. As per a paper presented by scientists of the Maharashtra Engineering Research Institute, a hydrographic survey of the Lower Bhawani reservoir was done in 1983. The MERI report also says that the project was impounded in 1953 and not in 1955 as mentioned in the SRS study.

⇒ Damanganga Report says the project installed hydropower capacity is 1000 MW, when that project is not known to have any hydropower component.

⇒ Siltation data not given in uniform units in all the reports, creating confusion and difficulty comparing the rates for different reservoirs. In case of Lower Bhawani reservoir, as in a number of other cases, the design siltation rate is not given.

⇒ While using the calculated values, simple scientific step of rounding the figures has not been done (e.g. siltation rate for Bhadar)

⇒ The report of Sondur Reservoir siltation (p 26) says the graph is for Umiam reservoir!

⇒ The report of Krishnaraj Sagar Reservoir SRS study (p 28) says that LS of *Lower Bhawani* reservoir is 1215.94 MCM when KRS should have been written.

⇒ The report on SRS study of Kadana reservoir ends with salient features of Mahi Bajaj Sagar (and preface for MBS) in place of salient features of Kadana.

What can be done? While it is not possible to totally avoid or stop siltation, one way to reduce the siltation of the reservoirs is to do Catchment Area Treatment (CAT). CAT applies various techniques like plantation, gully plugging, check dams, etc in the degraded portions of the catchments to reduce the silt coming into the reservoirs. CAT plans are expected to be implemented before the project construction is over so that there is minimum siltation of the reservoirs once water storage in the reservoir is started. However here too the situation is alarming. Till almost mid 1980s, most River Valley projects did not have a CAT component. In case of some like Bhakra, where the project had a CAT component, according to the govt of India's Comptroller and Auditor General, there was not way to ascertain if any CAT had really been done on ground, while the money allocated for the CAT was all spent, indirectly hinting that nothing was really done.

Even in case of projects taken up after mid 1980s, while provision of CAT exists on paper, it largely remains just there, on paper. Most recent such examples are the World Bank funded 1500 MW Nathpa Jhakri Hydropower Project and the Jaiprakash Group's 300 MW Baspa project, both in Himachal Pradesh. Both projects were commissioned in 2003, but, the CAT plans are yet to be implemented. Nathpa Jhakri project is already facing serious problems due to this as the project had to be stopped due to high silt in the river for 25 days since April 2006 alone.

Conclusion The reservoir capacities have been created at the cost of thousands of crores of rupees and we continue to spend huge sums each year for creating additional storage capacities. Enormous social and environmental costs have also been paid in the creation of these capacities. However, we are doing practically nothing to stop the destruction of the capacities created with such massive investments. As per our current analysis, we are losing at least 1.95 BCM storage capacity through siltation every year, valued at about Rs 2017 crores at replacement costs. The losses are alarming and the consequences far reaching. For example, the power generation from the upgraded 15 MW installed capacity at the Gumti Dam in Tripura is so low that even the World Bank strategy paper for the North East (dated June 28, 2006) recommends exploration of decommissioning[3] of the dam.

By the time you wake up tomorrow morning, we would have lost storage capacity worth Rs 5.53 crores, and remember we are doing nothing to stop that destruction.

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[3] Decommissioning means removal of the dam wall to allow free flow of the river.