A case study on sedimentation and sustainable plans and approaches for Nizamsagar and Sriramsagar reservoirs

S. Narasimha Rao
Chief Engineer, Irrigation & CAD Dept, Govt of Telangana

K. Venkata Narayana
DyEE, Irrigation & CAD Dept, Govt of Telangana

N. Ravishankar
DyEE, Irrigation & CAD Dept, Govt of Telangana

ABSTRACT:

The issue of sedimentation in reservoirs poses a serious challenge for large dams in the context of climate change with increase in frequency of rainfall events, rapid urbanization, deforestation, soil-erosion, changes in the land-use pattern, poor agricultural practices and effect of dense settlements in the reservoir catchment area. The paper is a case study on reservoir sedimentation and sustainable plans and approaches for the two reservoirs, namely Nizamsagar reservoir and Sriramsagar in Godavari basin of State of Telangana, India. In view of the seriousness of the issue, Hydrograpahic surveys with sophisticated Bathymetric system were conducted for both the reservoirs to assess the sedimentation. In addition to the loss of reservoir storage capacity, the sedimentation is leading to malfunctioning and damage of appurtenances namely intakes, scour-sluices etc. As a sustainable measure Nizamsagar was remodelled by rising the FRL to increase the capacity by 6 TMC (211.88 Mcum) and by providing additional spillway. Further, in case of Sriramsagar project, adopting remedial measures like construction of silt arresting tanks, construction of check dams and afforestation in foreshore area and other alternative measures are implemented. The paper also dwells into constraints and required remedial measures in the management of reservoir sedimentation for safeguarding the storage capacity, thereby increasing the lifespan of the reservoir.

1. INTRODUCTION

The sedimentation in reservoirs poses a serious challenge for large dams threatening the useful life of reservoirs throughout the world. Sediment trapped behind dams reduces reservoir capacity and impairing functions of the dam infrastructure. In the context of climate change with increase in frequency of rainfall events, rapid urbanisation, deforestation, changes in the land use and land cover pattern, poor agricultural practices and effect of dense settlements in the reservoir catchment are responsible for soil erosion, causing siltation and eventually resulting in the loss of useful storage. Sediments in the reservoir are a consequence of soil erosion in the catchment area, entrainment of sediments in the water flow, their transportation through gullies, small stream and later through the main river. The problem of sedimentation is most distinct in regions with semi-arid or monsoon climate. Many water resources projects have been built on the sediment bearing streams in the past without due consideration to the effects of sedimentation. Difficulties are encountered in operating and maintaining of the engineering works due to the presence of sediment and thereby affecting the economic life of many of them and also making life shorter than anticipated. Therefore, it becomes necessary to evaluate the rate of silting of reservoir and provide

to take suitable measures so that benefits may accrue as planned over the entire period of economic life of the reservoir.

2.NIZAMSAGAR

Nizamsagar reservoir was constructed during the years 1923 to 1930 on Manjira River which is a major tributary of River Godavari. But, the canal and distribution system was completed as late as 1935. While designing of Nizamsagar reservoir provision was made in the form of dead storage for silt storage of 2882.67 Mcft with a level of canal off-take being at R.L. + 425.14 m (1362.00 ft). During construction, it seems it was found necessary to raise the sill to R.L. +415.75 m (1364.00 ft), which increased the dead storage capacity to 4100.00 mcft. Nine scouring sluices 8 feet wide and 15 feet high have been provided with sill at R.L. + 411.48 m (1350.00 ft) to admit a flood discharge of 37,800 c/s with a head of 55 feet with water at M.W.L. R.L. 428.25 m (1405.00 ft). Further, the project authorities thought that when Devnoor is constructed on the upstream, it will trap a large part of silt in the reservoir. It was not feared, that, with the above dead storage provision and Devnoor project, the life of reservoir would be short and inglorious. As early as 1939, reports were received from the villages on the foreshore of the reservoir that the depth in the upper reaches of Nizamsagar was getting mainly reduced. In 1956-57, it was observed by the project authorities that daily drawls and depletion were not tallying with the reduction in water stored in the reservoir and it was noticed that excess depletion in the reservoir was of the order of 15% to 20% at various water levels. This was attributed to silting in reservoir. Then the project engineers tookup the direct surveys of contours. On the basis of these surveys, the capacity table of the reservoir was revised in 1961 and 1965 and at this stage it was felt necessary to assess the correct capacity of the reservoir, as loss in capacity from 1961 to 1965, itself appeared abnormal.

First time the Hydrographic surveys were conducted during 1967 and the capacity worked out as 402.91 M.cum (14.288 TMC) against the original capacity of 841.8 M.cum (29.706 TMC) which indicates the storage loss of 52 %. During the year 1973, the reservoir was practically dry due to drought and depletion of water of upto dead storage enable to take up repairs of the scour sluices. The project authorities have taken up cross sections of the reservoir bed. Based on these cross sections, the capacity of reservoir was worked out to be 354 M.cum(12.501 TMC). Repeat hydrographic surveys of the reservoir were conducted during 1975 and the capacity worked out as 362.40 M.cum (12.80 TMC) against the original capacity of 841.18 M.cum (29.706 TMC) and the loss of storage worked out as 57%.

Remodelling works

To restore the lost capacity due to the siltation and to safeguard the ayacut, the project was remodelled by the construction of bed regulator in place of saddle weirs I & II with 20 gates (additional spillway) to discharge 2.73 lakh cusecs for a maximum flood discharge of 6.31 lakh and also raising the FRL from 426.87 m to 428.25 m. After remodelling of the project, the live Capacity of the project was increased from 11.74 TMC to 17.80 TMC.

Further Hydrographic surveys

During the year 1992, Hydrographic survey was conducted and the capacity worked out as 496.70 M.cum (17.54 TMC) for the revised F.R.L of +428.24m and 332.52 M.cum (11.74 TMC) corresponding to the original F.R.L. of 426.87m. The rate of sedimentation was reduced and it worked out as 4.225 ha-m per 100 Sq.km. of catchment area per year. The Hydrograpahic survey has been conducted in Nizamsagar Project during Nov 2013-Dec2013 using sophisticated Integrated Bathymetric System (IBS). The Remote sensing Satellite Imagery of FRL +428.24 m was used for planning the Hydrographic survey. The range lines are drawn at interval of 250 m to 500 m normal to the stream flow from dam line to the mouth of the reservoir. Survey was started parallel to the Dam line and carried towards upstream of reservoir. The Navisoft survey software continuously recorded the reservoir depth and horizontal coordinates as the survey boat moved along the predetermined range lines throughout the reservoir. The survey vessels's guidance system provided directions to the boat operator to assist in maintaining the course along these predetermined range lines. Depth data was collected at an interval of 5 m along the range lines. The collected Hydrogrphic survey data wad edited for the freak values. As per Hydrographic survey conducted in 2013, the gross capacity worked out as 520.381 M.cum (18.377 TMC) for the present FRL of +428.240 m (1405.00 ft) and 377.563 M.cum (13.334 TMC) for the previous FRL of +426.87 m (1400.50 ft). This amount to a storage loss of 320.799 M.cum (11.32 TMC) which works out 39% comparing to original capacity and for raised FRL, the annual storage loss comes to 0.46%. The rate of siltation works out to 3.8 Ha.m/100Sq.km/year. In terms of catchment, the rate of siltation has also been reduced from 6.37 Ha-m/100 Sq.Km /year to 3.8 Ha-m/100 Sq.Km / year for FRL +426.87m. This may be mainly due to construction of projects in the upstream of Nizamsagar reservoir from the year 1966 onwards.

The siltation in the Nizamsagar reservoir as indicated from successive repeat surveys, showed a declining trend. The loss of storage as observed during the surveys of 1961 was 46%, where as it is 60% based on the Hydrographic surveys of 1992.Though the loss of storage is 46% in the first 31 years of operation (1930-1961), it is only 14% during the later part of 31 years (1961-1992). This is mainly due to the construction of barrage and storage reservoir (with 849 M.cum capacity) across the same river at 80 Km and 130 Km respectively upstream of Nizamsagar reservoir in Andhra Pradesh. Two more major reservoirs in the catchment of Manjira (viz) Lower Thirna in Maharashtra and Karanja in Karnataka portion of catchment are coming up. Besides these major projects, numbers of medium irrigation projects are under construction on the same river and its tributaries on upstream of Nizamsagar reservoir. When these reservoirs are completed, the rate of siltation in Nizamsagar reservoir would further get reduced. The details of surveys shown in Table 1.

Table 1. The survey results of Nizamsagar reservoir in various years

(Fig. are in TMC)

Capacity	Original Survey 1930 FRL +426.87	1967	1975	1992		2014	
				Previous FRL +426.87	Present FRL +428.24	Previous FRL +426.87	Present FRL +428.24
1	2	3	4	5	6	7	8
Gross	29.71	14.23	12.80	11.74	17.54	13.33	18.38
Live	25.598	14.11	-	11.743	17.536	13.243	18.293
Dead	4.107	0.118	-	0	0	0.084	0.084
Loss of Storage Capacity							
Gross		15.477	16.908	17.963	12.170	16.379	11.329
Live		11,488				12.355	7.305
Dead		3.989		17.96	12.17	4.024	4.024
Annual loss in Capacity in TMC		0.418	0.376	0.290	0.196	0.197	0.136
Annual % loss in capacity		1.41	1.54	0.98	0.45	0.66	0.46
Rate of Siltation (Ha-m/100sq.km/year		6.35	5.70	4.40	6.46	3.00	4.49

From the Sedimentation analysis, it is observed that the percentage of loss in capacity is on higher side than the contemplated. It is suggested to take catchment area treatment as per the guidelines to extend the life of reservoir. The conventional measures such as afforestation, contour bunding, terrain formation and construction of check dams can be adopted to arrest soil erosion. Much attention is to be given in training the farmers to adopt modern methods of cultivation in the catchment area for arresting top soil erosion in the fields.

3.SRI RAM SAGAR PROJECT

Siramasagar Reservoir is a Major Irrigation Project built across River Godavari at its Km.637 with a gross storage capacity of 112 TMC at FRL 1091 ft intended to provide Irrigation facilities in 9.68 lakh acres. The water was first impounded in 1970. Crest gates were erected during 1984 and the reservoir attained FRL for the first time in the same year. The useful life of a storage reservoir depends upon the rate of sediment deposition in the reservoir. At the planning stage of the reservoir, a provision of dead storage to extent of 30 TMC was made, assuming the life of the reservoir as 100 years to accommodate the silt deposition. This has been revised taking the recommended silt rate of 1.20 acres ft/sq mile/year by the Central Water Commission. Based on this it is expected that 35 TMC silt gets deposited in the first 50 years and 65 TMC in next 100 years.

In order to assess the rate of silt deposition, Hydrographic surveys of the reservoir were conducted in 1984, dividing the reservoir area into 19 ranges with an interval of 2 Km. and echo-soundings were done at these locations. Results of these surveys giving silt deposition of 20 TMC in one year could not be considered accurate as the 2 km interval adopted was very large. Repeat Hydrographic surveys were carried out again during 1994 taking soundings on the range lines set 0.5 Km. apart, dividing reservoir into 54 ranges and soundings taken at intervals of 60 m on each range line. The Gross Capacity computed was 90.31 TMC. Hydrographic surveys for second time in SRSP reservoir takenup with sophisticated Bathymetric system in 2006 and gross storage

capacity as 79.96 TMC. At present water storage capacity with 90.31 TMC as per Hydrographic surveys conducted in 1994, is being followed for calculation of inflows and outflows. Though Hydrographic surveys conducted during the year-2006 shows the capacity as 79.96 TMC, but it is observed that the water availability / utilization is much higher than the capacity reported.

Further, Hydrograpahic Survey was conducted in December 2013/ January 2014 using sophisticated Integrated Bathymetric System (IBS). Survey work was started at foreshore area and carried on towards Dam site. Depth data was collected at an interval of 5 m along the range lines. The remote sensing Satellite Imagery data at FRL +332.537 m is used as FRL contour plan the post processing. The contour areas are obtained from Surfer software. It was reported that there is loss of storage to an extent of 10TMC and the present gross capacity is only 80.104 TMC. The results of all above studies are compared and tabulated in Table 2 shown below:

Table 2. The survey results of Sri Ram sagar reservoir in various years

(Fig. in TMC)

	Original Capacity in 1970	Hydrographic surveys during		
		APERL 1994	APERL 2006	APERL 2014
Storage Capacity				
Gross	112.02	90.31	79.96	80.104
Live	81.19	70.72	65.99	64.547
Dead	30.83	19.59	13.97	15.557
Loss of Storage Capacity				
Gross		21.71	32.06	31.912
Live		10.47	15.20	16.640
Dead		11.24	16.86	15.273
Annual % loss in capacity		0.81%	0.79%	0.647
Rate of Siltation (Ha-m/100sq..km/year Acre ft/sq mile/year		4.74 or 1.00 acre ft/Sq mild/year	4.67 0.985 acre ft/Sq mild/year	3.8 or 0.802 acre ft/Sq mild/year

From the above table, it resembles that the annul percentage loss in reservoir storage capacity is reduced over the period of time from 0.81% to 0.647%. This is due to adoption of remedial measures like construction of silt arresting tanks, construction of check dams and afforestation in foreshore area and other alternative measures. Remedial measures taken to arrest siltation:

1) Construction of Silt arresting tanks.
2) Construction of Check Dams.
3) Afforestation in Foreshore area.

152 No's of SATs (Silt Arresting Tanks) and 26 No's of check dams were takenup to arrest siltation in SRS reservoir. Avenue Plantation (Afforestation) was raised in foreshore area of S.R.S.P. Reservoir in Adilabad District by spending 26 crores towards construction SATs and Check dams upto the year 1999.

4.CONCLUSIONS

a) The rate of siltation as observed in case of SRSP and Nizamsagar provides the importance of monitor the rate of sediment deposition after construction of dams.
b) The measurements of sediment load in the stream well in advance so that sufficient data may be on hand to predict the life of the reservoir. The observations of silt and sediment load in streams big or small invariably be made regularly to save the future loss in the utilization capacity of reservoirs.
c) Semi arid areas like Telangana are more prone to the soil erosion and deposition of sedimentation in the reservoirs will become the major issue and necessary soil conservation measures are required.
d) In view of implications of climate change and frequent possibility of occurrence of extreme events, there will be further increase of siltation of reservoirs due to the possibility of large scale of erosion on the account of change in the land use pattern.
e) Measurement of Sedimentation by Mathematical models needs to be developed for the major projects that relate loss of storage capacity of reservoirs due to the parameters influencing surface runoff and soil erosion in the reservoir catchments.
f) Preventive measures may be taken up to extend the life of the large dam to reap the maximum benefits as amount spent on the preventive measures is meagre compared to the capital cost and intems of the benefits accrued form the project. Minimum of 100 crores per annum may be appropriate to salve life of major projects from sedimentation issues as part of flood mitigation measures.
g) Periodic surveys of reservoirs may be taken up to assess the rate of sedimentation in the reservoirs with a separate wing having exclusive Central financial assistance.
h) In case of projects affected by heavy sedimentation, subsidiary dams may be takenup on the stream in the catchments to extend the life of large dams.
i) Additional bed regulators in the bund alignment may be helpful in flushing out the soil depositions by making suitable arrangements.

5.REFERENCES

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