WORKSHOP

ON

RESERVOIR SEDIMENTATION ASSESSMENT USING REMOTE SENSING DATA

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Module 5

Capacity Evaluation and Sedimentation Study of Manjra Reservoir by Remote Sensing Method

BY

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CAPACITY EVALUATION AND SEDIMENTATION STUDY OF MANJRA RESERVOIR BY REMOTE SENSING METHOD

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SYNOPSIS

Use of quick and accurate solutions to the problems in water management have to be frequently resorted to in the fast changing senario of the urban and rural population. Reservoir operation has certainly been getting enourmous importance due to the thrust put on the management in scarcity years. Use of remote sensing satellite data for arriving at the revised reservoir capacity evaluation and sedimentation study has ,therefore, been made in M.E.R.I. In this paper, an effort is made to overcome the limitations of using remote sensing method in case of Manjra reservoir in Maharashtra .

1.0 INTRODUCTION

Use of remote sensing satellite data to arrive at the revised capacity evaluation is limited to only live storage, as the reservoirs are generally operated within it. However, owing to scarcity of drinking water, and declining rainfall in the Marathwada region of Maharashtra, many reservoirs have to be operated frequently below M.D.D.L.levels. During 1994 - 95 the reservoirs could hardly be filled half and depleted to great extent, below M.D.D.L. Manjra reservoir on Manjra river near Latur and Nathsagar reservoir on Godavari near Aurangabad in Maharashtra were among them, both catering to drinking water to the cities nearby. The present paper deals with the capacity evaluation and sedimentation study of one of these, i.e. Manjra reservoir, which filled about only half and went almost dry in 1995 summer.

The remote sensing studies hitherto limited to live storage estimation could only throw light upon the reduction in capacity and the sedimentation taken place within the live storage only. Secondly even within the live storage the studies have to be limited to the partial live storage , owing to partial filling of the reservoir and also due to the non availability of the cloud free scenes during the period when the level reaches to its maximum for that year. Although this limitation is adequate in order to assess the revised capacity of the reservoir within the operational levels, it however, is not adequate to study the distribution of incoming silt from the reservoir within the live storage and the dead storage. It is also inadequate in order to compare the sedimentation taken place in the reservoir with that obtained from the incoming silt load from the catchment. The acute scarcity of drinking water which forced the authorities to operate the reservoir to its bottom has thus thrown open the opportunity to carry out the study within the dead storage of the reservoir.

The main objective of the study was, therefore, to find out the reduction in capacity of the reservoir as compared to the original or revised reservoir area capacity table available for that reservoir, in the live and the dead storages and thereby estimate the accumulation of silt in these two. Based on these results, comparison can be made with the silt load that is coming into the reservoir, which may be obtained by using the proper silt load factor as per the revised norms for estimating the same, which in turn may be used to revise the silt load factor if necessary. The results also can be used to suggest some measures that may be necessary for arresting erosion in the catchment. It is well known that Remote Sensing technique can give the fast, cheap and the real time solution for such an estimation. Present facilities in M.E.R.I. are used for analyzing this problem.

2.0 MANJRA RESERVOIR

Salient details of Manjra reservoir pertaining to this study are as follows,

Gross storage : 250.700 Mm^3

Live storage	:	173.318 Mm^3
Dead storage	:	77.382 Mm^3
F.R.L.	:	641.870 m
M.D.D.L.	:	635.720 m
Year of Impounding	:	1982
Catchment Area	:	2373 sq.km.

3.0 SILT LOAD

As per C.W.C.'s recommended silt load factor, viz, 750 cum/ sq.km./ year, silt estimated in Manjra reservoir shall be,

Estimated silt = 750 * 2373 * 13
= 23.14 Mcum.

This silt load is supposed to be deposited in the Gross Storage of the reservoir. Its distribution in live storage and dead Storage is worked out with the help of the empirical study described in book named " Life Of Reservoirs ", published by the C.B.I.P. According to this, it is seen that the distribution of the total silt load in live and dead Storage of Manjra reservoir shall be in a ratio of 36 : 64 %.

4.0 METHODOLOGY

For estimation of silt by remote sensing technique following methodology is used. Water is known to absorb almost all the energy in the near Infra Red region of the electromagnetic spectrum that is reaching the earth from the sun. As LISS II sensor on board of IRS 1B and IRS P2 satellite provide us four discrete bands in the visible and near Infra Red region, images of these satellites are used to arrive at the boundary of the water bodies. Band ratio technique of using Infra Red and Green band data is used by M.E.R.I. to arrive at a ratio image of Infra Red to Green bands of IRS satellite. The Reflectance of water in Infra red band of IRS satellite is less than that in Green band and therefore, the ratio of Reflectance of Infra Red band to that of Green band becomes less than unity for water. However, for ground features other than water this ratio is always more than unity. This logic was used in developing an Image Analysis software in M.E.R.I.on PC based computer. This software was further used in counting the number of pixels of water. A pixel is the smallest element which can be identified by the satellite sensor, which incidentally for LISS-II sensor of IRS satellite is 36 m x 36 m. In addition to the PC based software, use of ERDAS, an international Image Analysis software, supported on the high resolution workstation, was also done, as the colour display capacity of the PC based software is fairly limited. This was used to set the threshold limits of i) Infra Red band Reflectance of water and ii) the ratio of the Infra Red to Green band Reflectance digital numbers. The digital data of satellite images that were purchased for Manjra reservoir were in the form of Cartridge Tapes (CCTs). Each one of them was downloaded on to the PC/ 486 computer and a Ratioed image was formed with the help of the software that is available. This Ratioed image was then displayed and the windows containing the required reservoir were extracted from the full image for further analysis. The area under water in this sub image was found out with the help of a facility available in this software. Areas of water which do not form the main reservoir were deducted from the total area of water in this sub image. As many scenes as were available were analyzed in the same way. From the areas thus found out at various reservoir levels, volumes, i.e. capacities, between the successive levels of reservoir were calculated. For this purpose, the well known Prismoidal formula is used which is as follows,

$$V = H / 3 * (A1 + A2 + \text{sqrt}(A1 * A2))$$

where V is volume, or capacity, between consecutive reservoir levels separated by H m, and A1and A2 are the areas of reservoir at those levels. Similarly , field data of the reservoir was collected in which the reservoir levels and the corresponding areas are made use of for arriving at the original area capacity table. To arrive at the estimation of silt, the

volume between two reservoir levels obtained by remote sensing method is deducted from that obtained from the original area capacity table.

5.0 DATA USED

Although the satellite scenes pertaining to the period in the summer 1995, in which the reservoir was depleted below M.D.D.L., the filling of this reservoir in the live storage was only partial in 1994. In order to study the sedimentation above these levels satellite data pertaining to the higher RLs upto F.R.L. were chosen from the preceding year, i.e. during 1993-94, in which fortunately the reservoir was filled to its maximum. For this reason, the sedimentation taken place within this period has been ignored.

Manjra reservoir lies in the Path no.28 and Row no.55 of the IRS satellite. The scenes containing full reservoir were obtained from N.R.S.A., Hyderabad. The digital satellite data of IRS 1B and P2 from its LISS-II sensor, which have a spatial resolution of 36 m, was used for the present study. Cloud free scenes for full reservoir level variation from F.R.L.to M.D.D.L. from 1993-94 to 1994-95 were selected at N.R.S.A., Hyderabad using Browsing facility. Scenes of following dates were used for the present study.

13-04-95 03-04-95 22-03-95 28-02-95
06-02-95 18-05-94 04-04-94 13-03-94 28-01-94

From the salient features of the reservoir and the reservoir levels obtained from field officers, (please refer Table 1) it is seen that the reservoir level variation during the above period i.e. from 28-01-94 to 21-05-95 is about 96 % in the live storage portion. In addition, , in the dead storage also, the study is carried out for the levels for which the data was available, i.e. upto reservoir 631.2 m which is about 4 m below M.D.D.L.

While it was possible to obtain the scenes to cover the maximum reservoir level variation, the scenes exactly near the M.D.D.L. could not be obtained owing to presence of louds. From Table 1, it is clear that near the M.D.D.L. there is a large interval of 4 m between the lowest level in live Storage and the highest level in dead Storage. For obtaining the silt separately for live and dead Storages, the results are interpolated for M.D.D.L.

6.0 RESULTS

The area was obtained by the remote sensing method described above for readable scenes for the dates given above and volumes between successive RLs . The cumulative volume up to that RL are calculated by the prismoidal formula. These are shown in the Table 1 enclosed which also shows the area and volume as per the original area capacity table supplied by the field authorities. The calculations of silt estimation in the reservoir level range are also done and shown in this Table 1. Fig.1 shows a graph drawn to show the original reservoir capacities and the capacities found out by remote sensing method for various RLs of the reservoir.

7.0 DISCUSSION

The F.R.L. the M.D.D.L. and the reservoir levels used in this study are as below:

Design F.R.L. 641.870 m Highest level 641.600 m
(for study by remote sensing)

Design M.D.D.L. 635.720 m Lowest level 631.950 m
(for study by remote sensing)

From Table 1 and the graph in Fig 1, it is seen that the gross capacity of this reservoir between the RLs chosen for study as indicated above is seen to have reduced by 12.95 %. The estimation of silt accumulation between these levels works out to 27.79 cum. Compared to the estimated silt deposition as calculated in paragraph 3, which is for the full storage of the reservoir the silt deposition now obtained is on higher side. Table 1 also shows separate calculations for live storage as well as dead storage. This shows that the silt deposition in the live storage is 15.27 Mcum and that in dead storage is 11.78 Mcum. for the levels studied. Of the total silt the live storage deposition is 9.27 % and that for dead storage is 23.2 %. This shows that the percentage of silt deposition in the live storage and dead storage arrived at by remote sensing method compares well with that obtained by empirical method and Silt Load Factor as described in paragraph 3.

8.0 LIMITATIONS OF RESULTS AND RECOMMENDATIONS

It will be seen that the procedure employed for silt estimation involves calculation of areas and their comparison by two different methods. whereas the original contour areas and capacities may have been estimated on the basis of toposheets or actual ground survey, the areas worked out for building up fresh area and capacity curve for this study are by remote sensing techniques. Actually, these two techniques being different, the results of comparison and estimation have limitations on this account. However, if further studies of silt estimation by remote sensing are continued at periodical interval of, say three to five years, the results will give successive silt accumulation in live storage and the technique being the same can give an accurate trend of silt deposition in the reservoir live storage.M.E.R.I. is planning to continue the studies of some reservoirs periodically.

9.0 CONCLUSIONS

Use of remote sensing satellite can be very effectively used to study the sedimentation in the reservoir, even within the dead storage during the scarcity period. This in turn can be used to ascertain the rate and the distribution of sedimentation in the reservoir and to revise the silt load factor and for planning necessary treatment for arresting the erosion in the catchment area.

10.0 REFERENCES

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STUDY OF STORAGE CAPACITY OF MANJRA RESERVOIR

MANJRA : 1994-95
F.R.L. : 641.870 m.
M.D.D.L. : 635.720 m.

PRISMOIDAL FORMULA
V= (L/3)*((A1+A2)+@SQRT(A1*A2))

SR NO	RESERVOIR R.L.	AS PER PROJECT DETAILS			BY REMOTE SENSING METHOD			REDUCTION IN VOLUME OF WATER IN STRIP	CUMULA-TIVE REDUCTION IN VOLUME OF WATER	PERCENT REDUCTION IN VOLUME OF WATER	REMARK
		DESIGNED WATER SPREAD	DESIGNED VOLUME OF WATER STRIP	DESIGNED CUMULATIVE VOLUME OF WATER	AREA OF WATER STRIP	VOLUME OF WATER STRIP	CUMULA-TIVE VOLUME OF WATER				
	M	M.Sqm.	M.cum	M.cum	M.sqm	M.cum	M.cum	M.cum	M.cum	%	
1	2	3	4	5	6	7	8	9	10	11	12
DEAD STORAGE											REDUC-TION
1	631.950	9.4925			6.0510						IN
2	632.800	11.1720	8.7727	8.7727	7.4805	5.7402	5.7402	3.0326	3.0326	34.568	DEAD
3	632.950	11.3955	1.6925	10.4653	7.7189	1.1399	6.8801	0.5526	3.5852	34.258	STORAGE
4	633.500	12.5300	6.5770	17.0423	8.7713	4.5317	11.4118	2.0453	5.6305	33.038	23.20
5	633.550	12.6350	0.6291	17.6714	9.2599	0.4507	11.8625	0.1784	5.8089	32.872	
6	635.72	18.0346	33.1033	50.7747	16.0547	27.1304	38.9929	5.9729	11.7818	23.204	
LIVE STORAGE											REDUC-TION
1	635.72	18.0346			16.0547						IN
2	637.900	23.4590	45.0986	45.0986	22.8808	42.2206	42.2206	2.8781	2.8781	6.382	LIVE
3	639.750	32.8275	51.8229	96.9216	28.2852	47.2403	89.4609	4.5826	7.4607	7.698	STORAGE
4	640.450	34.8250	23.6749	120.5965	30.7476	20.6555	110.1164	3.0194	10.4801	8.690	9.27
5	641.600	42.0820	44.1558	164.7523	37.8432	39.3692	149.4856	4.7866	15.2667	9.266	

FIG. 1. RL. v/s Cum. Capacity (MANJRA)

capacity curve for 1994-95