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Sedimentation Analysis of Ujani Dam

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Abstract -The sedimentation is an effect of erosion on the catchment area of the reservoir and therefore, lesser the rate of erosion, smaller is the sediment load coming into the reservoir. Deposition of sedimentation in the reservoir moderately reduces the capacity of the reservoir. Both Dead storage capacity & live storage capacity gets affected due to sedimentation. Information about reduction in the storage capacity is important for the planning and operational purposes and the same can be obtained by sediment assessment surveys done at regular intervals. Various factors affect the process of erosion, transport and deposition of sediment in the reservoir. Type of soil, drainage density, vegetation, rainfall intensity and duration, shape of catchment and land use / land cover affect erosion. Sediment transportation totally depends upon slope of the catchment, channel geometry and nature of river bank and bed. Deposition is a function of bed slope of the reservoir, length of reservoir, flow patterns, inflow-outflow rates, grain size distribution, mode of reservoir operation etc

Key Words: Ujani Dam, Sedimentation, Remote sensing

1.INTRODUCTION

India is the second ranked largest country in the world depending on the basis of population – has about 17.3% of world's population,approximately 4% of the world's water resources, and 2.44% of the total geographical land area of the world. Hence, in spite of having an average annual average precipitation to the tune of more than 1105 mm/year, the population density (lack of land resources) and per capita water resources availability Put together India a water-stressed country, as a whole. However, at a regional or basin level, more areas in the country are water-scarce or severely water-scarce due to the spatial and temporal variability of water resources.

It is estimated that average annual precipitation over India is about 3880 BCM. Out of this precipitation, the average annual water resources available in the country is about 1999. 2 BCM, as estimated by the Central Water Commission (CWC) in 2019. The water resources availability situation is getting murkier due to topographical and other constraints. Due to this, the total utilizable water resources in the country are about 1122 BCM (690 BCM of surface water and 432 BCM of groundwater). On one hand, the per-capita water resource availability is reducing due to increasing population and on the other, per-capita water usage is increasing due to industrialisation, urbanization and change in lifestyles or dietary habits, making the available water resources still dearer.

India has typical monsoon-based climate where more than 75% rainfall occurs in three months i.e. July, August, and September. The total number of rainy days typically are in the tune of only 20-25 days per year (100-150 hours of rain per year) for most parts of the country. As a result, the bulk of annual water (75-80%) in rivers is available only in these three months.Therefore, in order to sustain life and other activities throughout the year from resources that are available only through 20-25 rainy days, it is absolutely essential to store the water in appropriately-sized storage structures (depending upon the topography and hydrology of the area).So far, India has developed just 257.812 BCM as live storage capacity and 46.765 BCM is under construction. Realizing the importance of storage structures, a large number of reservoirs have been built, since independence, during each plan in almost all river basins, except Ganga and Brahmaputra, for drawing the water to the ground level when needed. The capacity of reservoirs is gradually reducing due to silting and hence sedimentation of reservoir is of great concern for all the water resources development projects.for better determination of storage capacity of reservoir i.e optimal capacity one must adhere to the study of sedimentation and loss of dam.Since 1958, due to the soil erosion and siltation live capacity of reservoir getting lowed there is need to do combine efforts against it.

Various techniques like boat echo sounder, etc. being replaced by hydrographic data acquisition system (HYDAC) and HITECH method using Differential Global Positioning System (DGPS). Use of methods is necessary as old methods are lengthy and time consuming .Remote sensing technique to calculate the present live capacity of a reservoir is found to be very useful in this context due to its synoptic and repetitive coverage. The surveys based on remote sensing data are faster, economical and more reliable. These surveys will enable selection of appropriate measures for controlling sedimentation along with efficient management and operation of reservoirs thereby deriving maximum benefits for the society.This report covers the study of Ujjani reservoir, Maharashtra by Central Water Commission,New Delhi.

Fig -1: Sediments in Submergence

2 STUDY AREA

Fig -2: Upstream Side of Ujjani Dam

The Ujani dam is situated on the Bhima river in Ujani village in Madha taluka, Solapur district.. The dam site is located at 180 04' 24" N latitude and 750 07' 15" E longitude. The location of the dam is shown in Figure 4 as Index Map.The Ujani dam serves a multipurpose of irrigation, hydro power and drinking water. The total catchment area at the dam site is 14856 sq km and free catchment area is 9766 Sq km.. The dam was completed in 1980. The FRL and MWL of the reservoir are at a level of 496.830 m and 497.580 m respectively. The dead storage and live storage capacity of Ujjani dam are 1802.81 Mm3 and 1517.20 Mm3 respectively.The average annual rainfall near dam site is 500 mm, and average annual rainfall runoff is 7585 M.cum (267.83 TMC).There are two main canals taking off from the reservoir. The length of the right main canal is 112 km + branches. The right main canal has a gross command area of 61252 hectares. The length of the left main canal is 126 km + branches. The left main canal has a gross command area of 95608 hectares. The total gross command area is 156860 hectares.

METHODOLOGY

The basic approach is to estimate the water-spread areas from satellite data for different water levels between MDDL to FRL. The difference between areal spread of water between current year and earlier years gives the areal extent of silting at these levels. The methodology for calculation of live capacity And Dead capacity of reservoir using remote sensing consists of following major tasks

(i) Digital database creation
(ii) Estimation of water-spread area
(iii) Calculation of reservoir capacity
(iv) Comparison of result with previous surveys
(v) Calculation of Live storage capacity due to siltation

In this we are going to use hybrid method i.e remote sensing in combination with DGPS bathymetric survey

Remote Sensing in Reservoir Sedimentation

Remote sensing is the art and science of collecting information about earth's features without being in physical contact with it. Earth can deflect the solar rays and various alfa , beta rays due to the layer of gasses surrounding it. The reflected radiation depends upon physical properties of the terrain and emitted radiation depends upon temperature and emissivity. The radiation is recorded by the sensors onboard the satellite and then are transmitted back to earth. Different result can be achieved through it as various areas have different topography and level of vegetation. Data received at ground stations, is digitally or visually interpreted to generate thematic maps.Data acquisition is done from various polar orbiting satellites (orbiting around 800 to 900 km altitude), namely Indian Remote Sensing (IRS) satellite, European Remote Sensing (ERS) satellite, Landsat and SPOT satellites.Data from these satellites are being received and archived by National Remote Sensing Centre (NRSC) at Hyderabad.Present study utilizes data from Resourcesat 1, Resourcesat 2 and Resourcesat 2A satellite. They have a LISS III sensor, which operates in four spectral bands. Three bands are in the visible and near infrared region with spectral band widths as 0.52-0.59 m, 0.62-0.68 m and 0.77-0.86m and spatial resolution as 23.50 m. Fourth band with spectral bandwidth of 1.55-1.75 m falls in the short wave infrared region.Reservoir sedimentation surveys are essentially based on mapping of water-spread areas during the time of satellite overpass. It uses the principle that the water-spread area of the reservoir reduces with the sedimentation at different levels. a product of water stretch area gives the water holding capacity at different locations .These capacity values are then compared with the previously calculated capacity values to calculate change in capacity between different levels.

Table -1: Details of Satellite Data.

Sr. No.	Date of pass	Elevation (m)
1	12 - Mar – 2019	491.320
2	15 - Apr – 2017	491.825
3	23 - Jan – 2019	493.000
4	18 - Dec – 2018	494.140
5	14 - Feb – 2017	495.060
6	28 - Jan – 2018	496.045
7	16 - Dec – 2016	496. 890

Resourcesat 1, 2 and 2A LISS III images of 23.5 m resolution having Path 96, Row 60 have been used in present analysis. The dates of satellite pass of selected images and corresponding reservoir levels are given in Table 1.to prepare a list of dates of satellite pass over the Ujjani reservoir for the year 2016 to 2019. The reservoir levels on these dates along with corresponding water spread areas and capacities have been obtained from field officers.

The reservoir has been depleted up to 491.320 m as against MDDL (491.030 m). The maximum level covered in the present study is 496.890 m, which is near to FRL (496.830 m). Variation in the study level is (496.890 - 491.320) = 5.570 m. The difference between FRL and MDDL is (496.830 - 491.030) = 5.800 m. In the present study, storage of 1459.110 Mm3 has been covered as against total live capacity of 1517.200 Mm3. Thus the percentage live storage covered by this study is 96.171 %.

It is essentially based on mapping of water-spread areas during the time of satellite ove pass.It uses the fact that water-spread area of the reservoir reduces with the sedimentation occurring at different levels. a product of water stretch area gives the water holding capacity at different locations. These capacity values are then compared with the previously (originally) calculated capacity values to find out change in capacity between different levels. Remote Sensing technique is cheaper, faster and fairly accurate. It requires less manpower and no field job. The entire job is done in-house and therefore can be conducted in any part of the year. The method is suitable for reservoirs with large water spread areas also and the costing is independent of the size of the submergence area i.e. extent of reservoir. The study of a major reservoir can be completed in a span of 2-3 months. The survey can be taken in any part of the year and can be conducted for past period also if there is no sufficient depletion in water level in a single year, the study can be done using previous years data clubbed with current data Normally LISS III satellite images of about 24 m spatial resolution is used for such studies. The Indian Remote sensing Satellite (IRS) Resource sat images having 24 m spatial resolution has a wide coverage of 141 km x 141 km on the ground. One LISS III Satellite image can accommodate more than one reservoir (sometimes 4 to 5). The same satellite images can be used to conduct sedimentation surveys for other reservoirs also, covered in those images. This expenditure on the cost of the satellite data can be reduced drastically. But the main limitation of this technique is that the technique can be applied for a reservoir zone between FRL to the existing minimum water level in the reservoir only. It cannot be extended up to reservoir bed level. Secondly, cloud free satellite images for desired water levels in the reservoir are not always assured, especially during monsoon period.

Water spread area at regular interval

Water levels on the dates of pass for selected satellite data are not available at regular interval. However to get WSA values at regular interval of elevation, area-elevation curve is plotted for the reservoir and a second order polynomial has been fitted. area calculated at every one meter

Calculation of reservoir capacity

Table -2: Water spread areas extracted from satellite data.

Date of pass	Elevation (m)	Area (Mm^2)
12 - Mar – 2019	491.320	188.445
15 - Apr – 2017	491.825	194.924
23 - Jan – 2019	493.000	218.123
18 - Dec – 2018	494.140	236.383
14 - Feb – 2017	495.060	252.423
28 - Jan – 2018	496.045	266.363
16 - Dec – 2016	496. 890	282.030

Computation of reservoir capacities at different elevations have been derived using following formula

V = H / 3 * (A1 + A2 + SQRT (A1 * A2)).

Where V is reservoir capacity between two successive elevation of h1 and h2. H is the elevation difference, H = (h1 – h2) A1 and A2 are areas of reservoir water spread at elevation h1 and h2 respectively.The cumulative live capacities derived at different elevation have been shown in Table 2.

Table -3 : Areal extent and cumulative live storage capacity of reservoir at regular interval defined from Graph.

Water elevation m	Water spread area Mm^2 (2017-18)	Cumulative capacity Mm^3 (2017-18)
MDDL 491.030	182.300	0.000
492.000	199.564	185.141
493.000	216.991	393.357
494.000	234.042	618.820
495.000	250.718	861.152
496.000	267.017	1119.977
FRL 496.830	280.260	1347.074

The elevation-area curve drawn through original and present surveys carried out for Ujjani reservoir are shown in Figure 10 which is based on Table 2 .The elevation-capacity curve drawn through original and present surveys carried for the Ujjani reservoir are shown in Table 2 .It is updated SRS elevation-area-capacity curve is drawn and tabulated

DGPS BASED BATHYMETRIC SURVEY

The High Tech DGPS based Bathymetric Survey is accurate and reliable. It is also faster than conventional hydrographic survey and does not require much manpower. The cost of conducting DGPS Bathymetric survey depends on the size of the reservoir. For reservoirs with a large water spread area the survey becomes expensive. Another limitation of this method is that it requires about minimum 1.5-2 meters clearance between bed level and the bottom of the boat floating on the water. Thus this method also does not cover the entire reservoir portion from FRL to reservoir bed level. For reservoir portions of less than 2 meters depth, this survey is to be supplemented with ground survey by total station or by remote sensing. The survey is generally not undertaken during the monsoon period because of heavy inflow and Reservoirs coming into reservoirs. The Hydrographic survey is usually

undertaken when the reservoir is full so that the maximum reservoir zone is covered under the survey; such surveys normally start in the late October / November when the monsoon is almost over by that time. Considering all the practical difficulties while conducting an actual survey, a 2 months period is normally required for completing the field work i.e. actual survey of a major reservoir. At the most, 2-3 reservoirs can be covered in a single year if major part of storage is to be covered under hydrographic survey only. Taking into consideration the advantage and disadvantages of both the methods, it would be a wise approach to adopt hybrid technique, i.e. DGPS bathymetric survey in combination with remote sensing. In general, for reservoirs with large water spread areas (viz.m Jayakwadi, Ujjani etc) remote sensing technique can be applied for live storage portion since the cost of this survey is independent of magnitude of water spread and DGPS bathymetric survey can be applied (Jayakwadi and Ujjani) for the dead storage part where water spread area is much less. By doing so, the extent of submergence area to be surveyed under bathymetric survey is drastically reduced thereby reducing the cost of the survey as well as the time.Maharashtra Engineering Research Institute, MERI, Nashik which is R and D wing of the state's water Resources Department has been conducting reservoir sedimentation studies regularly. The institute has the necessary infrastructure facilities like remote sensing lab with state of the art computer system and standard image analysis software, and DGPS mounted boat with advanced computer system required to conduct the sediment assessment studies by both the methods either independently or in a blended manner. The experience gained after these surveys conducted by different techniques revealed that hybrid technique is definitely more economical, faster and less laborious and at the same time, reliable also.

Reservoir Survey Preparation

Ujjani reservoir survey preparation has been done in following stages.

1. Installation of DGPS reference station.
2. Launching of boat and installation of mobile station.
3. Installation of Echo sounder and SVP.
4. Installation of deets gathering display unit
5. Project chart and range lines

Table -4: Revised Area and Capacity through DGPS Survey.

Sr no	Elevation	Revised Area(Mm2)	Revised Capacity(Mm3)
1	458	0.0021	0.013
2	459	0.0296	0.043
3	460	0.0583	0.086
4	461	0.1161	1.664
5	462	4.178	6.058
6	463	8.158	9.617
7	464	11.153	13.132
8	465	15.215	17.819
9	466	20.556	22.76
10	467	25.037	27.247
11	468	29.518	32.174
12	469	34.905	35.104
13	470	35.304	36.106
14	471	36.914	37.113
15	472	37.313	38.791
16	473	40.289	40.8
17	474	41.313	43.09
18	475	44.891	46.71

Installation of DGPS reference station

The accuracy in the position is increased with the differential global positioning system involving the reference station and the mobile station. The first step in the DGPS based reservoir survey planning is to select the suitable location for establishing a GPS reference station preferably at the known coordinates and from where the GPS antenna will have a clear sky view . It was also confirmed from the supplier that when more than 3 satellites are within the inner circle of mobile GPS the position is more accurate in such case only mobile GPS can be used for positioning Hence mobile GPS was used for positioning.

Launching the boat and installation of the mobile statin:

The survey boat with twin mounted 60 HP engines was transported to the dam site by private transporter & launched with help of the crane at the reservoir and a suitable jetty place was selected for the boat. The boat mounted equipment the GPS mobile station MX420 with smart GPS antenna, UHF data link with UHF antenna, batteries of boat engine, and batteries of equipment were installed.The scrutiny vehicle are equipped with SONAR system to assist the captain . Global positioning receives the signal through the transmitter.

Installation of deets gathering display unit

A Pentium laptop PC with Windows XP operating system and installed with Navitronic software Navisoft was used for the hydrographic survey work. Mobile GPS is interfaced with the echo sounder AUXIN port. The echo sounder is interfaced with the laptop to the serial com port. The laptop used, has inbuilt VGA port which is interfaced with the additional LCD monitor (Helmsman display) for the boat driver to view the range lines to be surveyed

Fig -3: Bathymetric DGPS Surveying Boat

Installation of the echo sounder:

Echo sounder NAVISOUND NS 415 was installed at the boat.The echo sounder was calibrated with the help of calibrator. The sound velocity obtained by calibrator was noted as the sound velocity is input to the echo sounder in the echo sounder set up. The transducer was fitted the transducer well provided in the boat properly and connected to the echo sounder. The necessary setting of the initial lock out for channels, draught, TX power and receiver gain were done in the echo sounder setup menu

Project chart and range lines

The bathymetric survey software (Lavasoft survey software) used consists of various modules to support the survey activities.

1. Planning and presentation
2. Survey
3. Calculate
4. Data edit
5. Data exchange

The final output to the display unit provide a 3d mapping and Iconographic survey.

design. It has following options:

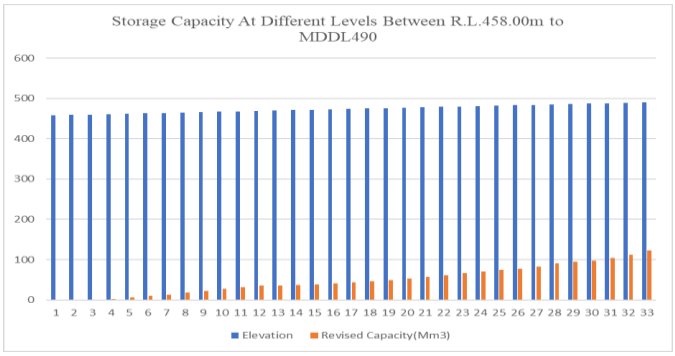
Chart set up
Header set up
Object set up
Segment set up
Symbol set up
Grid set up

At the start of work, two points near the left banks were selected. Coordinates of these two points were rad from the mobile GPS IN UTM system. A chart with suitable dimensions is selected in the chart set up. To plan the survey, the coordinates of these two points were used to draw a reference line. This was done with the help of a chart setup program. The range lines with spacing 100m were generated with the Auto lines option in the segment set up. The range lines with spacing 200m, 300m were generated in the upstream end area of the reservoir. Additional lines required to cover the reservoir area manually drawn on the chart during the survey. The final output is saved as docx.file then it can be used to draw survey coordinates .Survey team has adopted a closer interval for range lines in the project chart, in order to secure accurate results. In General, range lines are taken at the interval of 300 to 500 m for major reservoirs.

Hybrid Method-

In this part, the result of DGPS bathymetric survey and remote sensing survey are clubbed together to estimate total siltation in reservoir from reservoir bed level to FRL. The sedimentation study of Ujjani reservoir by Hybrid Technique of joint DGPS bathymetric survey and remote sensing survey covered entire reservoir portion and hence reduction in capacity in the total reservoir portion at different elevations could be estimated.Either DGPS bathymetric survey or remote sensing survey alone would not have covered entire reservoir. The amount of silt is estimated as the difference between original capacity and the present capacity.A table giving present area and storage capacity at different elevations at an interval of 1 meter is enclosed below.The loss in live storage capacity of the reservoir in remote sensing survey (2017-18) due to sedimentation since original survey

Chart 1- Storage at Different Levels



3. CONCLUSIONS

Following conclusions can are made from the study:

TABLE 4- Revised Capacity By Hybrid method

Remark	Sr.NO	Elevation	Revised Area Mm2	Revised Capacity Mm3	CUM. DS/L.S	CUMMULATIVE Gross Mm3	Orignal Capacity Mm3	Loss in Capacity Mm3	Cumm. Orignal capacity Mm3	Total Loss in Capacity Mm3
DEAD Water Storage	1	458	0.0021	0.013	0.013	0.013	0.018	0.005		
	2	459	0.0296	0.043	0.056	0.056	0.050	0.007		
	3	460	0.0583	0.086	0.142	0.142	0.154	0.068		
	4	461	0.1161	1.664	1.805	1.805	2.326	0.662		
	5	462	4.178	6.058	7.863	7.863	6.729	0.671		
	6	463	8.158	9.617	17.480	17.480	10.812	0.495		
	7	464	11.153	13.132	30.612	30.612	13.793	0.661		
	8	465	15.215	17.819	48.430	48.430	18.339	0.52		
	9	466	20.556	22.760	71.190	71.190	23.279	0.519		
	10	467	25.037	27.247	98.437	98.437	27.724	0.477		
	11	468	29.518	32.174	130.611	130.611	32.984	0.81		
	12	469	34.905	35.104	165.715	165.715	35.716	0.612		
	13	470	35.304	36.106	201.821	201.821	36.503	0.497		
	14	471	36.914	37.113	238.934	238.934	37.930	0.817		
	15	472	37.313	38.791	277.726	277.726	39.025	0.334		
	16	473	40.289	40.800	318.526	318.526	41.217	0.417		
	17	474	41.313	43.090	361.615	361.615	43.871	0.781		
	18	475	44.891	46.710	408.325	408.325	47.304	0.594		
	19	476	48.552	49.514	457.839	457.839	49.992	0.478		
	20	477	50.482	53.040	510.879	510.879	53.391	0.351		
	21	478	55.64	56.823	567.702	567.702	57.380	0.557		
	22	479	58.015	60.695	628.397	628.397	61.493	0.798		
	23	480	63.415	66.151	694.548	694.548	66.764	0.613		
	24	481	68.925	70.634	765.182	765.182	71.349	0.715		
	25	482	72.356	74.080	839.261	839.261	74.869	0.789		
	26	483	75.817	77.658	916.920	916.920	78.069	0.511		
	27	484	79.514	82.988	999.908	999.908	83.869	0.881		
	28	485	86.512	90.026	1089.934	1089.934	90.558	0.532		
	29	486	93.587	94.863	1184.797	1184.797	95.421	0.558		
	30	487	96.144	97.642	1282.439	1282.439	98.038	0.496		
	31	488	99.148	104.319	1386.758	1386.758	104.820	0.501		
	32	489	109.58	112.646	1499.404	1499.404	113.024	0.378		
	33	490	115.74	122.106	1621.511	1621.511	122.598	0.492		
	34	491	128.58	162.778	1784.288	1784.288	163.192	0.414	1802.299	18.011
Live Water Storage	35	492	199.56	185.148	185.141	1969.436	212.698	27.55		
	36	493	216.99	208.217	393.365	2177.653	237.687	29.47		
	37	494	234.04	225.463	618.827	2403.116	253.814	28.351		
	38	495	250.72	242.332	861.159	2645.448	268.462	26.13		
	39	496	267.02	258.825	1119.984	2904.273	288.302	29.477		
	40	4968.3	280.06	227.098	1347.082	3131.370	256.216	29.118	1517.175	170.096

For conducting reservoir sedimentation surveys the Hybrid technique of DGPS bathymetric survey in combination with remote sensing survey is found to be very useful. It is very economical,faster, less laborious and reliable also. This survey covers the entire reservoir portion from bed level to FRL. The study revealed that present gross storage capacity of Ujjani reservoir is 3131.37 Mm3 against original gross storage capacity of 3319.47 Mm3.The difference between original & The present gross capacity is only 188.107 Mm3 which is moderate. However the reservoir is 37 years old; it is seen that 18.011 Mm3 storage capacity loss in the dead storage zone while capacity loss in live storage zone by 170.096 Mm3.It may be possible due to sedimentation of the dam. The upstream flow is very strong in catchment area of ujani thus causing these sedimentation loss in capacity of dam.Thus We can Conclude That The current live storage capacity of Ujjani reservoir is worked out to be 1347.074 Mm3 The Current Dead storage capacity of Ujjani reservoir is 1784.288 Mm3 Capacity loss of 11.213 % in live storage is observed in a period of 37 years since first impounding .
Annual Gross capacity loss works out to be 0.152% for the last 37 years.

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