उपग्रह दूरस्थ संवेदन द्वारा
रवीशंकर सागर जलाशय, छत्तीसगड का अवसादन आंकलन

Sedimentation Assessment of Ravishankar Sagar Reservoir, Chhattisgarh, through Satellite Remote Sensing

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JUNE 2016

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FOREWORD

Acknowledgement

The Project Team is thankful for the guidance provided by Chief Engineer (EMO), CWC, and Director, Remote Sensing Directorate, CWC, New Delhi in completing the work of "Sedimentation Assessment Study of Thirty (30) Reservoirs in India through Remote Sensing Technique" and in particular the present study of Ravishankar Reservoir.

The project team is thankful to the Secretary (CAD), Water Resources Department, Government of Maharashtra for his keen interest and constant encouragement in completion of this study. Our special thanks are due to Shri. R. V. Panse, Director General, MERI and Shri. R. V. Shrigiriwar, Superintending Engineer, MERI for their valuable support and motivation for carrying out this work.

Our thanks are also due to Shri. K. S. Dhruw, Superintending Engineer, Dam circle, Rudri, Shri. Ajay Sharma, Executive Engineer, W.M. Division, Rudri for the keen interest shown in the work. We are also thankful to Shri. S. K. Netam, Sub-divisional officer, Shri. S. K. Nag Choudary, Sub Engineer of W. M. Sub-Division No.9, Gangrel for supplying all relevant data required for the present analysis.

PROJECT TEAM

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Abbreviations

AOI	Area of Interest
μm	Micro metre
CWC	Central Water Commission
DGPS	Differential Global Positioning System
ERS	European Remote Sensing satellite
FCC	False Color Composite
FRL	Full Reservoir Level
IR	Infra red
IRS	Indian Remote Sensing Satellite
LISS	Linear Imaging Self Scanning Sensor
MDDL	Minimum Draw Down Level
MERI	Maharashtra Engineering Research Institute
MOU	Memorandum of Understanding
MWL	Maximum Water Level
NDVI	Normalized Difference Vegetation Index
NIR	Near Infra red
NRSC	National Remote Sensing Centre
R	Red band
SAT	Shift Along Track
SQRT	Square Root
SRS	Satellite Remote Sensing
WSA	Water Spread Area

Units used

ha	Hectare
km	Kilometre
m	Metre
m^3/s	Metre cube per second
Mm^2	Million square metre
Mm^3	Million cubic metre
MW	Mega watt
sq km	Square kilometre

EXECUTIVE SUMMARY

Water resources sector has got high priority in all our developmental plans and accordingly large numbers of dams have been constructed to supply water for domestic, irrigation and industrial purposes. Natural processes like erosion in the catchment area and its deposition in various parts of the reservoir gradually reduce the capacity of the reservoir. Dead as well as live storages get affected by it. The information about the reduction in capacity is necessary for all planning and operational purposes, which can be obtained through capacity surveys done at regular interval. The Remote Sensing technique can be used to calculate present capacity of the reservoir. It is very useful due to its simple analysis procedure and repetitive coverage by imagery. The surveys based on remote sensing data are faster, economical and more reliable. Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India has initiated the programme to evaluate capacity of various reservoirs in the country. Accordingly the Central Water Commission has entrusted MERI, Nashik the work of "Sedimentation Assessment Study of Thirty (30) Reservoirs in India through Remote Sensing Technique". The present study is in regard to Ravishankar Sagar Reservoir, Chhattisgarh State, India.

Present study aims in updating the elevation-area-capacity curve of Ravishankar Sagar Reservoir, Chhattisgarh and finding the capacity loss due to sedimentation in live storage. For carrying out the analysis, IRS P6 and Resourcesat 2 *LISS III data with 23.5 m resolution have been used. Satellite data for nine passes falling between MDDL (336.21 m) and FRL (348.70 m) are used for the analysis.*

The Ravishankar Sagar Dam is located on the Mahanadi River. The dam site is located near Gangrel village in taluka and district Dhamtari. The construction of dam was completed in 1979. The project has a designed gross reservoir capacity of 910.50 Mm^3, with live capacity of 766.90 Mm^3.

This study reveals that the present live capacity of reservoir is reduced by 22.117 Mm^3 witnessing a loss of 2.88 % in a period of 34 years from original survey in year 1979. This amounts to 0.08 % loss per annum in live storage since 1979.

SEDIMENTATION ASSESSMENT OF RAVISHANKAR SAGAR RESERVOIR, CHHATTISGARH THROUGH SATELLITE REMOTE SENSING

1. Introduction

All our developmental plans have given high priority to water resources projects involving construction of dams and a large number of dams have been constructed since independence. The capacity of reservoirs is gradually reducing due to silting and hence sedimentation of reservoir is of great concern to all the water resources development agencies. Silting encroaches in dead as well as live capacity of the reservoir. This reduction in capacity has both long and short-range impact on the functioning of the project and on economics. Sedimentation adversely affects irrigation planning, power generation, drinking water supply and flood moderation. Correct assessment of sedimentation rate is essential for estimating useful life of the reservoir and preparing reservoir operation schedule. Since 1958, when it was established that the live storage of the reservoir is getting reduced due to siltation, a systematic effort has been made by agencies to evaluate the capacity of reservoir. The conventional technique like boat echo sounder has been replaced by hydrographic data acquisition system (HYDAC) and HITECH method using Differential Global Positioning System (DGPS). The conventional techniques were time consuming, costly and requiring considerable manpower. In this context the remote sensing technique to evaluate the present reservoir live capacity is found to be very useful, due to its synoptic and repetitive coverage. Further the surveys based on remote sensing data are faster and economical.

Impact of sedimentation on multipurpose reservoir is more significant. In some of the reservoirs, the rate of sedimentation has been higher than what has been considered at the planning stage. Some reservoirs in the world have been silted up so fast that they have lost large capacity. Many of the reservoirs in India are losing capacity at the rate of 0.2 to 1 percent annually. Therefore, it has become necessary to conduct sedimentation survey of the existing reservoirs. This will also make data available for deriving siltation indices of different regions and river basins on the basis of which the future design of reservoirs can be planned. These surveys also help in selection of appropriate measures for controlling sedimentation, efficient management and operation of reservoirs. Recent observations have brought to light the alarming fact that the reservoir sedimentation resulting from watershed degradation is much higher than the designed rate of erosion.

Appreciating the importance of sedimentation problems the Government of India constituted a Working Group of National Action Plan for reservoir sedimentation assessment. Accordingly, on recommendations of the Group, the Ministry of Water Resources, Government of India formulated a list of reservoirs to be taken up in 10^{th} five year plan for sedimentation assessment.

The present report deals with the study of Ravishankar Sagar Reservoir, of Dhamtari district of Chhattisgarh. This work is carried out for Central Water Commission, New Delhi under the project "Sedimentation Assessment Study of 30 Reservoirs in India through Remote Sensing".

2. Mechanism of Sedimentation

In order to obtain the knowledge of sedimentation in the reservoir, it is necessary to study the mechanism of sedimentation. The objective of such study is to mitigate reservoir sedimentation thereby prolong the life span of reservoirs and take full benefits of the reservoirs. Characteristics of reservoir sedimentation include quantity, distribution and composition of sediment deposits.

As water enters a reservoir, its velocity diminishes because of the increased cross sectional area of the channel. If the water stored in the reservoir is clear and the inflow is muddy, the two fluids have different densities and the heavy turbid water flows along the channel bottom towards the dam under gravity. This condition is known as "stratified flow" and the underflow is called a "density current". In a general sense, a density current may be defined as a gravity flow and fluids of approximately equal density. From Figure 1 it may be seen that the depth of the turbid flow increases to the point where the density current is established after which it tends to decrease again (Varshney, 1977).

The magnitude of sediment deposition and relative change therefore depend on many factors such as reservoir shape, channel slopes, relation of outflow to inflow and fluid density differences. It is observed that the density currents move very slowly. In many respects deposits in a reservoir resemble those in a delta area near to lake or sea (Varshney, 1997). The sediment deposit in different beds namely

i) Bottom set beds consisting of the fine sediments brought in by the stream,
ii) The fore-set beds formed of the coarser sandy sediments,
iii) Top set beds consisting of coarser particles and
iv) Density current deposits as shown in Figure 1 (Varshney, 1997).

As a general rule, smaller sizes of material progressively get deposited beyond the delta front, resulting in a gradual downward slope of the reservoir bed. Much of the wash-load carried by stream may not settle out as the cross sectional area of the stream increases at the entry of the reservoir. Furthermore, the suspension may not mix completely with the clear water of the reservoir because of their difference in specific gravity. The gravity underflow i.e. density currents move through the entire length of the reservoir. This portion of the flow is collected as a submerged pool, forming almost level floor in the deepest part of the reservoir, where it gradually compacts provided it is not disturbed by turbulence (Varshney, 1997).

The sedimentation is a product of erosion in the catchment areas of the reservoir and hence lesser the rate of erosion, smaller is the sediment load entering the reservoir. Various factors govern the detachment, transport and deposition of the sediment viz. Type of soil, drainage density, vegetation, rainfall intensity and duration, shape of catchment and land use and land cover effect the detachment. Sediment transportation 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. (Varshney, 1997).

Earlier it was believed that sediment always gets deposited in the bottom elevations of reservoir affecting the dead storage rather than depositing throughout the full range of reservoir depths. It is now established that deposition takes place throughout the reservoir reducing the incremental capacity at all elevations.

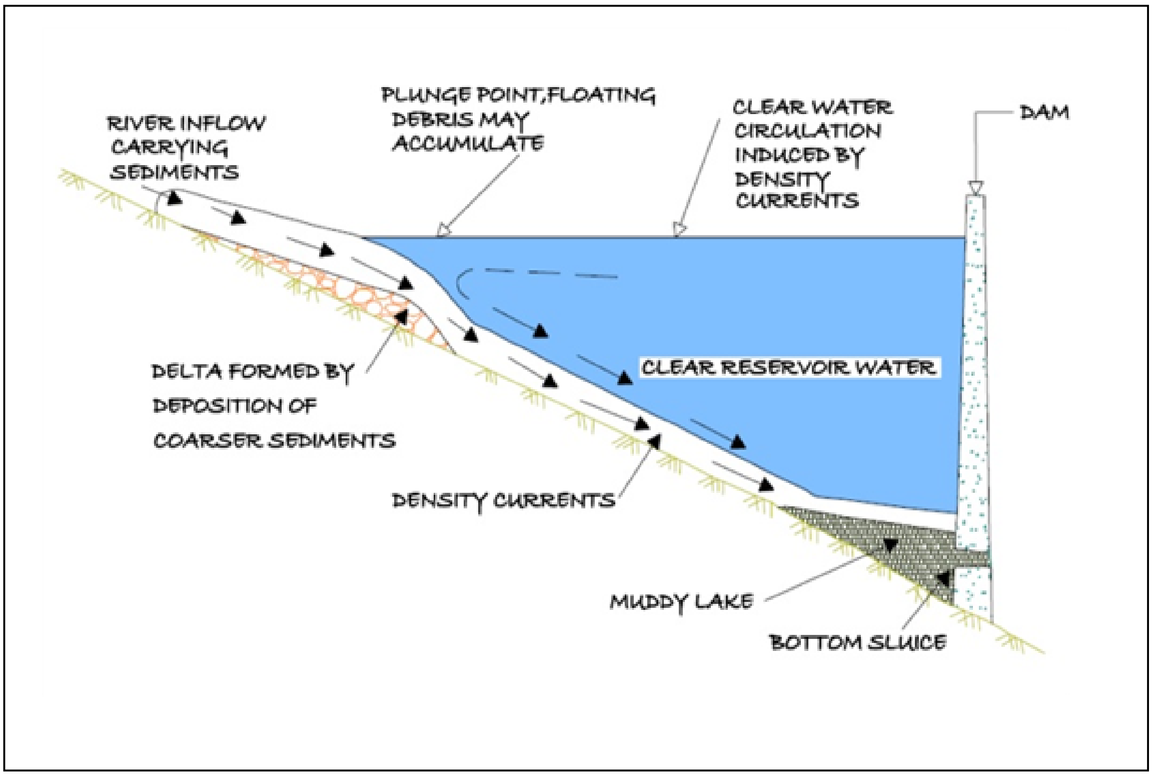

Figure 1 : Conceptual sketch of density currents and sediment deposits in a reservoir (Varshney, 1997)

Several factors like amount of sediment quantity, particle size distribution, fluctuations in stream discharge, shape of reservoir, stream valley slope, vegetation at the head of the reservoir, location and size of outlets, etc., control the location of sediment deposits in the reservoir. Figure 2 shows different control levels in the reservoir.

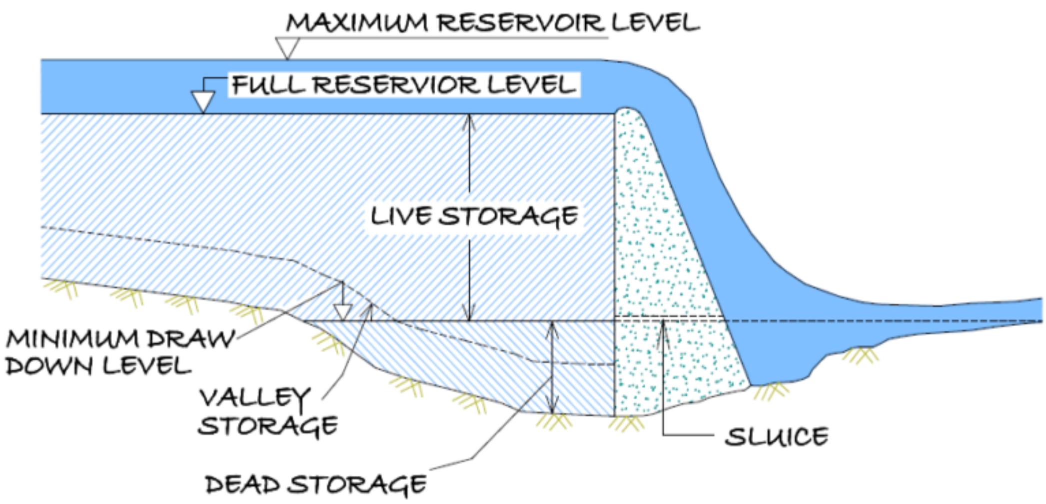

Figure 2 : Conceptual sketch of different levels in a reservoir

Reservoir operates between minimum draw down level (MDDL) to full reservoir level (FRL). The storage between these two levels is the live storage. The storage below MDDL is the dead storage. Water stored along the valley bed is known as valley storage (Agrawal, Nakil, et.al., 2011).

3. Remote Sensing in Reservoir Sedimentation

Remote sensing is the art and science of collecting information about earth's feature without being in physical contact with it. Various features on earth surface reflect or emit electromagnetic energy depending upon their characteristics. The reflected radiation depends upon physical properties of the terrain and emitted radiation depends upon temperature and emissivity. The radiations are recorded by the sensors onboard satellite and then are transmitted back to earth. Discrimination between features depends on the fact that the response from different features like vegetation, soil, water is different and discernable. 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 IRS P6 and Resourcesat 2 satellite. They have LISS III sensor, which operates in four spectral bands. Three bands are in the visible and near infra red region with spectral band widths as 0.52-0.59 μm, 0.62-0.68 μm and 0.77-0.86 μm and spatial resolution as 23.5 m. Fourth band with spectral bandwidth of 1.55-1.75 μm falls in short wave infra red region.

Reservoir sedimentation surveys are essentially based on mapping of water-spread areas at the time of satellite over pass. It uses the fact that water-spread area of the reservoir reduces with the sedimentation at different levels. The water-spread area and the elevation information are used to calculate the volume of water stored between different levels. These capacity values are then compared with the previously calculated capacity values to find out change in capacity between different levels.

4. Objectives

The objective of the study is to estimate capacity loss of Ravishankar Sagar reservoir due to sedimentation through satellite remote sensing. Following objectives will be achieved in the study.

(i) Updating of Elevation-Area-Capacity curve using satellite data in live storage zone of Ravishankar Sagar reservoir.

(ii) Estimation of live storage loss due to sedimentation in Ravishankar Sagar reservoir.

5. Study Area

The Ravishankar Sagar reservoir is located near Gangrel village in Taluka and District Dhamtari of Chhattisgarh State, on the Mahanadi river. The dam site is located at 20^0 37' 00" N latitude and 81^0 34' 00" E longitudes. The location of the dam is shown in Figure 3 - Index Map.

The Ravishankar Sagar dam was completed in the year 1979. The catchment area at the dam site is 3670 sq km. The dam serves dual purpose of irrigation and power generation. The FRL and MDDL of the reservoir are at a level of 348.70 m and 336.21 m respectively. The gross storage and live storage capacity of Ravishankar Sagar dam at FRL are 910.50 $Mm^3$and 766.90 Mm^3 respectively. The dead storage is 143.60 Mm^3.

The scheme envisaged construction of an earth dam in the river bed to a maximum height of 47 m. There is one feeder canal having design capacity of 19.83 m^3/s (700.26 cusecs). For power generation consist of 4 no. propeller standard turbines each of 2.5 MW capacity, to be installed. Salient features of Ravishankar Sagar project are given in Annexure I.

6. Previous Surveys

Previous hydrographic survey of Ravishankar Sagar has been conducted in year 2003. Summary of this survey is shown in Table 1.

Table 1 : Summary of previous survey

Details of surveys	Live capacity (Mm^3)	Cumulative loss	Cumulative % loss
Original survey (1979)	766.90	-	-
Hydrographic survey (2003)	757.12	9.78	1.28

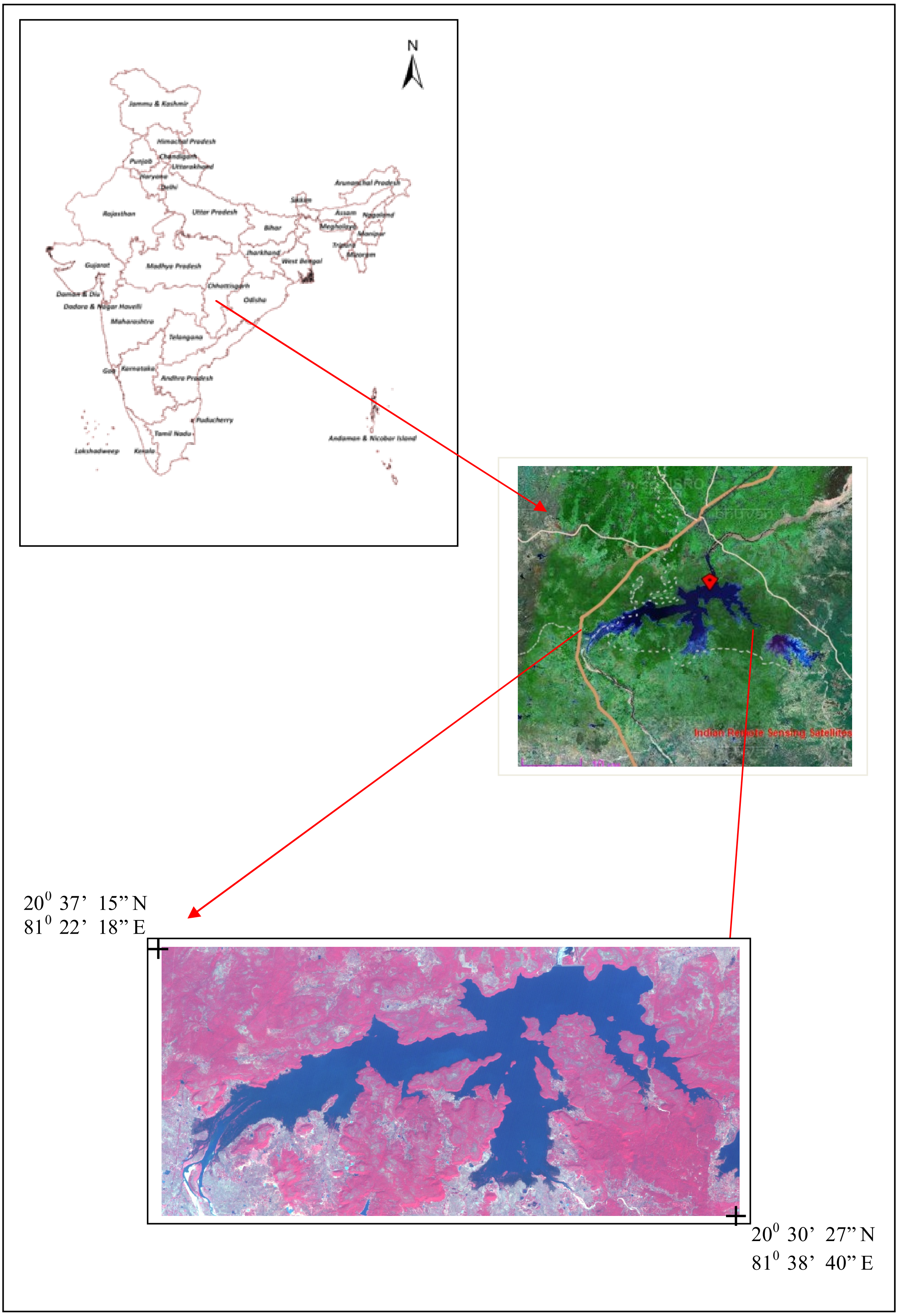

Figure 3 : Index map of Ravishankar Sagar reservoir, Chhattisgarh

7. Approach of Present Study

Remote sensing technique is utilized to assess the sedimentation between operating levels of reservoir. This operating range between MDDL (336.21 m) and FRL (348.70 m) varies each year and depends upon yield in the reservoir and utilization of the water. During years 2013 to 2014 the minimum and maximum level in this reservoir fluctuated in various range. This is shown in Table 2. The cloud free levels in this range are selected for analysis.

Table 2: Status of cloud free levels achieved during 2012 to 2014

Water year	Minimum level (m)	Maximum level (m)	Difference of minimum and maximum levels (m)
2012-13	338.42	344.14	5.72
2013-14	341.55	348.69	7.14

The information reveals that in the water year 2013-14, reservoir was filled up to FRL while it got depleted to RL 338.42 m in water year 2012-13. Six images from water year 2013-14 and three images from water year 2013-14 have been used. The year of survey of present study is treated as 2013-14.

8. Data

8.1 Field data

Following data set was obtained from Executive Engineer, Water Management Division, Rudri for Ravishankar Sagar reservoir and used in the present analysis.

i) Index map of reservoir

ii) Latitude and longitude of the reservoir

iii) Original area capacity table at 0.01m interval.

iv) Salient features of the project

v) Reservoir levels for given dates of satellite pass.

8.2 Satellite data

IRS P6 and Resourcesat 2 LISS III images of 23.5 m resolution having Path 102, Row 58 have been used in the present analysis. The FCC of the images are as given in Figure 4. The dates of satellite pass of selected images and corresponding reservoir levels are given in Table 3.

Table 3 : Details of satellite data

Sr. no.	Date of pass	Elevation (m)	Sr. no.	Date of pass	Elevation (m)
1	02-Dec-2013	348.69	6	07-May-2014	342.73
2	24-Feb-2014	347.38	7	31-May-2014	341.55
3	01-Apr-2014	345.93	8	30-Apr-2013	340.16
4	01-Mar-2013	344.14	9	24-May-2013	338.42
5	25-Apr-2014	343.33			

8.3 Criteria for satellite dates selection

The selection of the satellite data for the present study is based on the following guidelines given in the MOU signed between CWC, New Delhi and MERI, Nashik.

(i) To carry out the feasibility assessment of the given reservoir regarding availability of cloud free satellite data of dates of satellite pass corresponding to reservoir levels near MDDL as well as near FRL and at uniform interval to the extent possible in between MDDL and FRL for the latest water year or maximum up to two previous water years.

(ii) To carry out sedimentation analysis through SRS technique to cover the entire live storage zone of the reservoir.

(iii) In case of inability to cover the entire live storage zone of the reservoir due to non-availability of cloud free satellite data at FRL and MDDL, the study may be taken up if minimum of 80 % of live storage capacity is covered by the available cloud free dates of satellite pass on maximum and minimum reservoir levels.

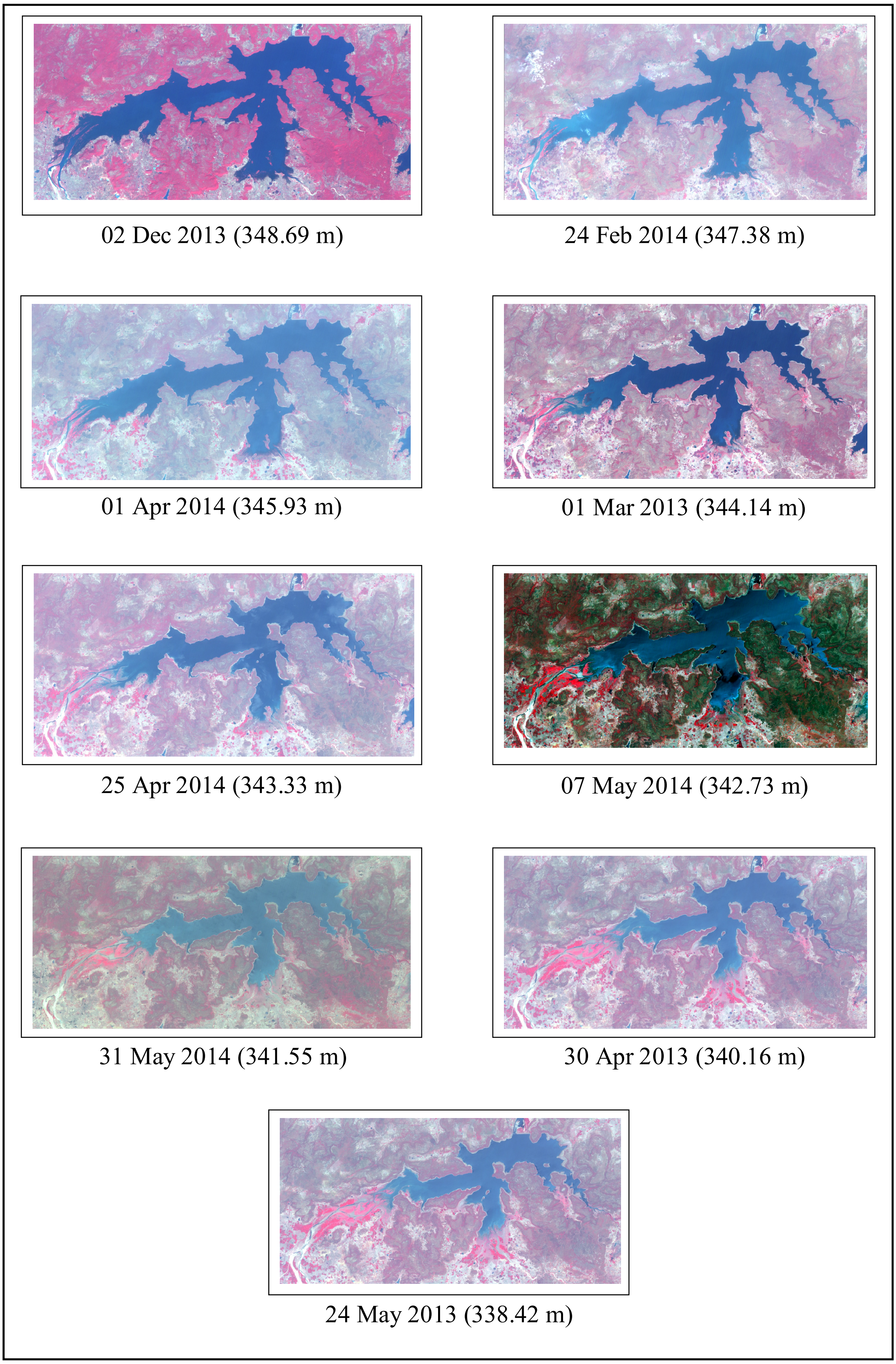

Figure 4 : FCC's of Ravishankar Sagar reservoir, Chhattisgarh

NRSC website has been browsed to prepare a list of dates of satellite pass over the Ravishankar Sagar reservoir for year 2013 to 2014. The reservoir levels as on these dates along with corresponding water spread areas and capacities are obtained from field officers.

The reservoir has been depleted up to 338.42 m as against MDDL (336.21 m). The maximum level covered in the present study is 348.69 m that is near to FRL (348.70 m). Variation in the study level is (348.69 – 338.42) = 10.27 m. The difference between FRL and MDDL is (348.70 – 336.21) = 12.49 m.

In the present study, the storage of 688.53 Mm^3 has been covered as against total live capacity of 766.90 Mm^3. Thus the percentage live storage covered by this study is 89.78 %. (Annexure II)

Statement giving cloud free dates of satellite pass, reservoir levels, areas and capacities for the Ravishankar Sagar reservoir has been prepared and submitted to CWC. The CWC has finalized the dates and placed the order of images with NRSC, Hyderabad. The data has been received directly by MERI from NRSC, Hyderabad.

9. Software Used

The analysis is done using the software ERDAS IMAGINE Ver. 2010. This software provides facility for satellite image analysis, by different methods.

10. Methodology

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

(i) Digital data base creation
(ii) Estimation of water-spread area
(iii) Calculation of reservoir capacity
(iv) Comparison of result with previous surveys
(v) Estimation of live capacity loss due to sedimentation

10.1 Procedural flow chart

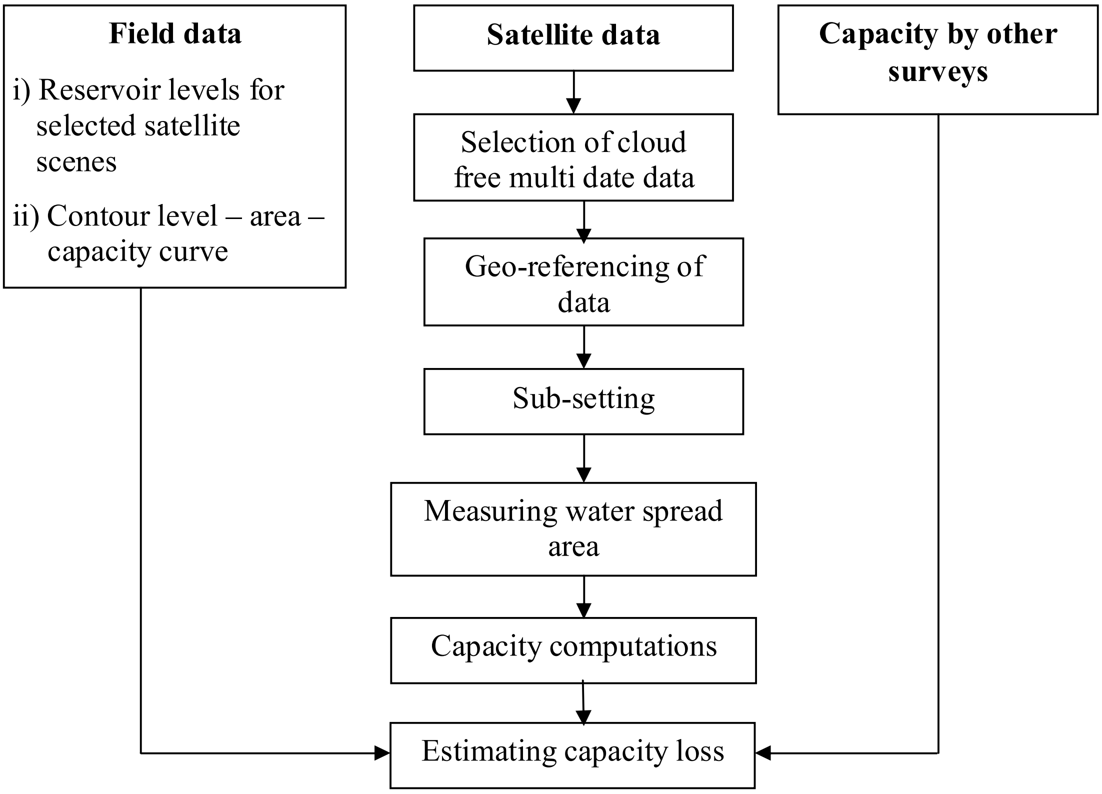

Figure 5 : Flow chart showing methodology for reservoir capacity estimation

10.2 Data loading

All the scenes are loaded in the system. These are listed as different files. They are renamed corresponding to falling levels. It helps in identifying the images during analysis. These files are in *.img* formats.

10.3 Image geo-referencing

Geo-referenced ready satellite images have been used in the analysis. However, when all the images are superimposed and swiped, slight displacements of images are noticed. Treating the image of the highest water level as the base image all the remaining images are again geo-referenced using image to image option of the ERDAS IMAGINE software.

10.4 Area extraction

A subset of the rectified scene is defined so as to facilitate and use in subsequent analysis. Rectified scene is loaded on the system. A small area around reservoir is extracted from one scene in interactive way. Once the area of interest (AOI) is finalized other scenes are extracted using the same AOI.

10.5 Water spread area extraction

Area extraction is done by either Normalized Difference Vegetation Index (NDVI) or by classification. NDVI is one index which distinguishes vegetation and water. Positive values indicate vegetation whereas negative values correspond to water. NDVI is generated using the formula given below.

$$NDVI = (NIR - R) / (NIR + R)$$

Where NIR is digital number in near infrared band and R is digital number in red band. The ratioed image is then density sliced. Water pixels generally occupy lower range of histogram in ratioed image. For Ravishankar Sagar reservoir NDVI outputs are generated for each scene and range of NDVI for water body delineation is noted for each scene. The range of NDVI values are given in Table 4**.**

Table 4 : Range of NDVI values for Ravishankar Sagar reservoir

Date of pass	Minimum value	Maximum value
02-Dec-2013	- 0.1428	+ 0.1835
24-Feb-2014	- 0.3953	- 0.1119
01-Apr-2014	- 0.0838	+ 0.0770
01-Mar-2013	- 0.4615	- 0.1075
25-Apr-2014	- 0.0867	+ 0.0576
07-May-2014	- 0.3103	- 0.1363
31-May-2014	- 0.2465	- 0.1297
30-Apr-2013	- 0.0909	+ 0.0667
24-May-2013	- 0.0909	+ 0.0667

Using the above range of values, water spread areas are extracted for all the scenes. The Water Spread Areas (WSA) derived for all the scenes and their corresponding water levels are shown in Table 5.

Table 5 : Water spread areas estimated from satellite data

Date of pass	Elevation (m)	Area (Mm^2)
24-May-2013	338.42	38.269
30-Apr-2013	340.16	48.165
31-May-2014	341.55	55.291
7-May-2014	342.73	61.262
25-Apr-2014	343.33	64.183
1-Mar-2013	344.14	67.556
1-Apr-2014	345.93	78.202
24-Feb-2014	347.38	86.004
2-Dec-2013	348.69	91.369

The water spread areas on selected dates of satellite pass are shown in Figure 6. The tail of the reservoir is defined by removing the river portion from extracted WSA, carefully.

10.6 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. The areas at an elevation interval of 1.0 m are computed from this best fit equation. These values are given in Table 6.

10.7 Calculation of reservoir capacity

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

$$V = h/3*[A_1 + A_2 + SQRT\ (A_1 * A_2)].$$

Where V is reservoir capacity between two successive elevation of h_1 and h_2

h is the elevation difference = $(h_1 – h_2)$

A_1 and A_2 are areas of reservoir water spread at elevation h_1 and h_2 respectively.

The cumulative live capacities derived at different elevation have been shown in Table 6.

Table 6 : Areal extent and cumulative live storage capacity of reservoir at regular interval defined from graph

Water elevation (m)	**Water spread area 2013-14 (Mm^2)**	**Cumulative live capacity 2013-14 (Mm^3)**
MDDL 336.21	26.660	0.000
337.00	30.905	22.718
338.00	36.257	56.263
339.00	41.585	95.154
340.00	46.889	139.364
341.00	52.169	188.870
342.00	57.425	243.646
343.00	62.657	303.668
344.00	67.865	368.911
345.00	73.049	439.352
346.00	78.209	514.967
347.00	83.345	595.730
348.00	88.458	681.619
FRL 348.70	92.022	744.783

SRS elevation area curve is shown in Figure 7 and tabulated in Table 5. Elevation capacity curve is shown in Figure 8 and tabulated in Table 6. The elevation-area curves drawn through original and present surveys carried out for Ravishankar Sagar reservoir are shown in Figure 9 which is based on Table 7. The elevation-capacity curves drawn through original and present surveys carried for the Ravishankar Sagar reservoir are shown in Figure 10 and tabulated in Table 8. In Figure 11 updated SRS elevation-area-capacity curve is drawn and tabulated in Table 6.

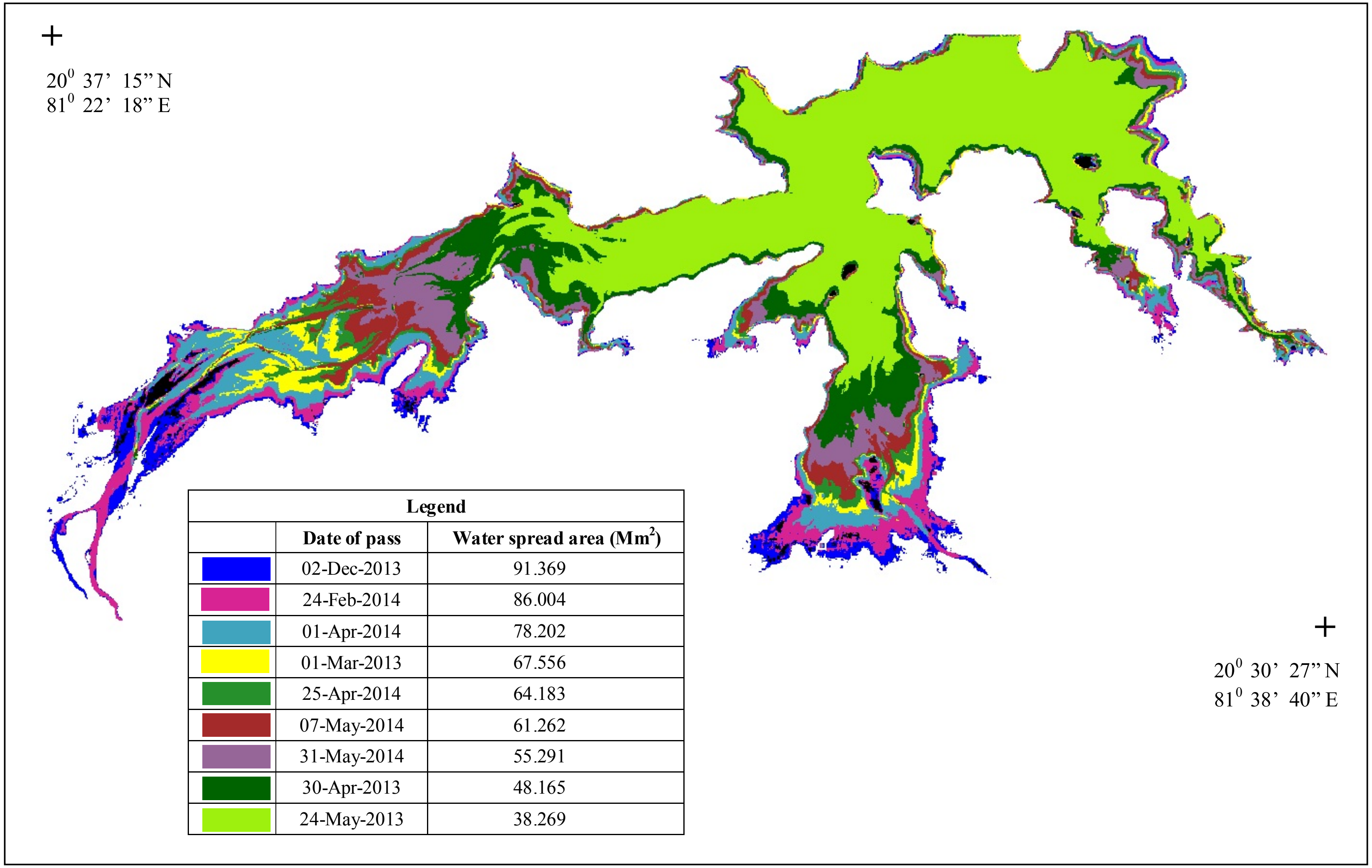

Figure 6 : Water spread areas on different dates of satellite pass

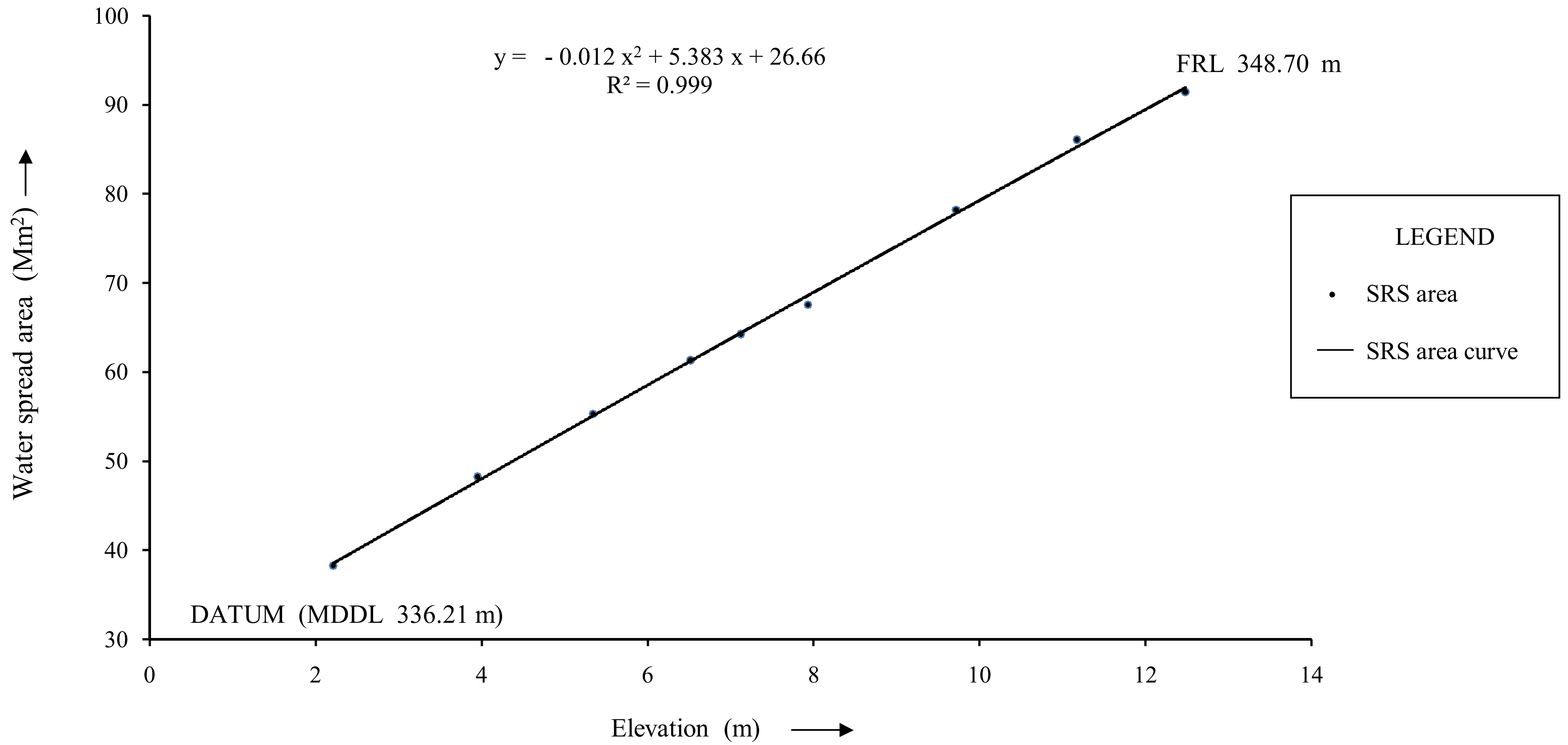

Figure 7 : SRS elevation - area curve for Ravishankar Sagar reservoir, Chhattisgarh

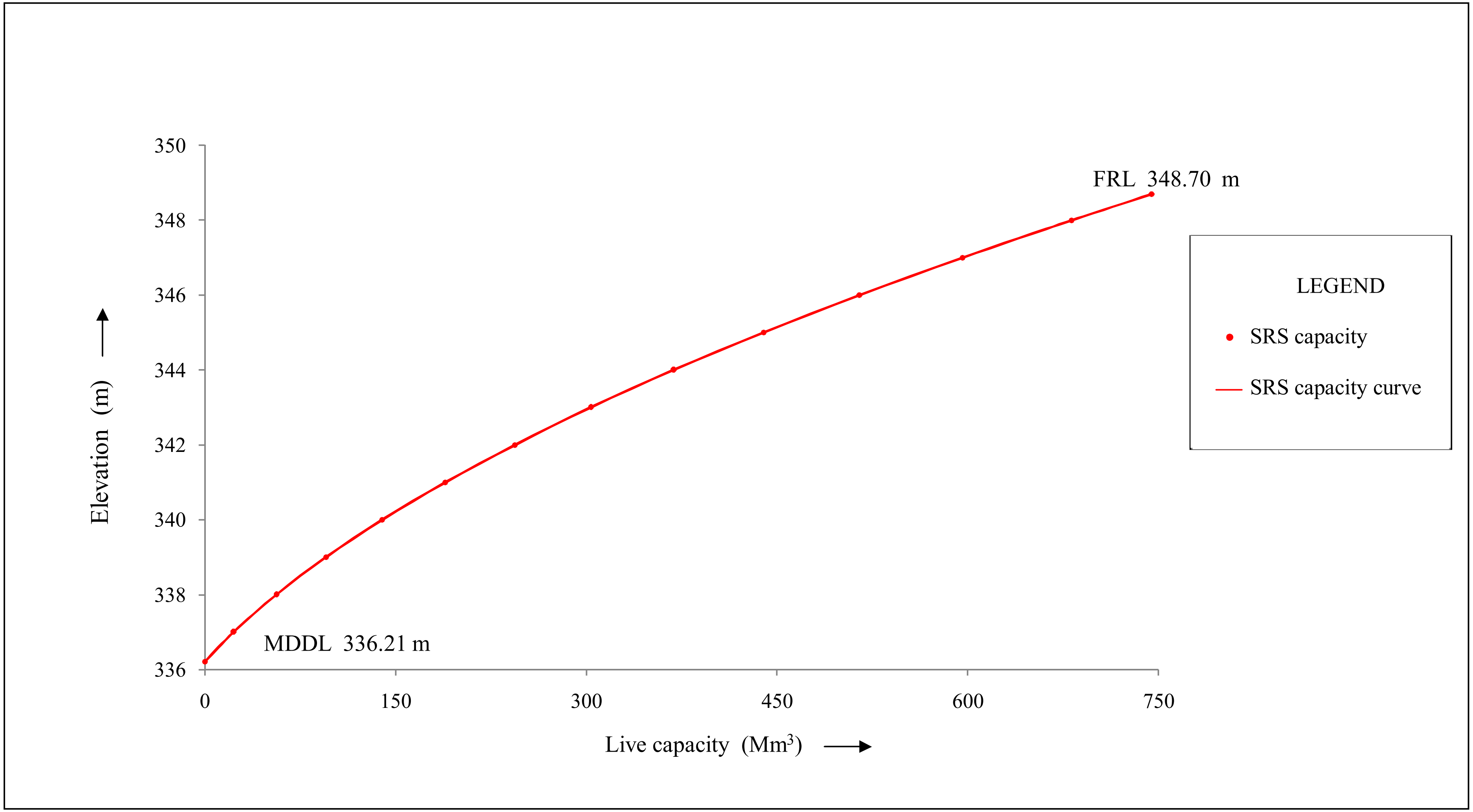

Figure 8 : SRS elevation - capacity curve for Ravishankar Sagar reservoir, Chhattisgarh

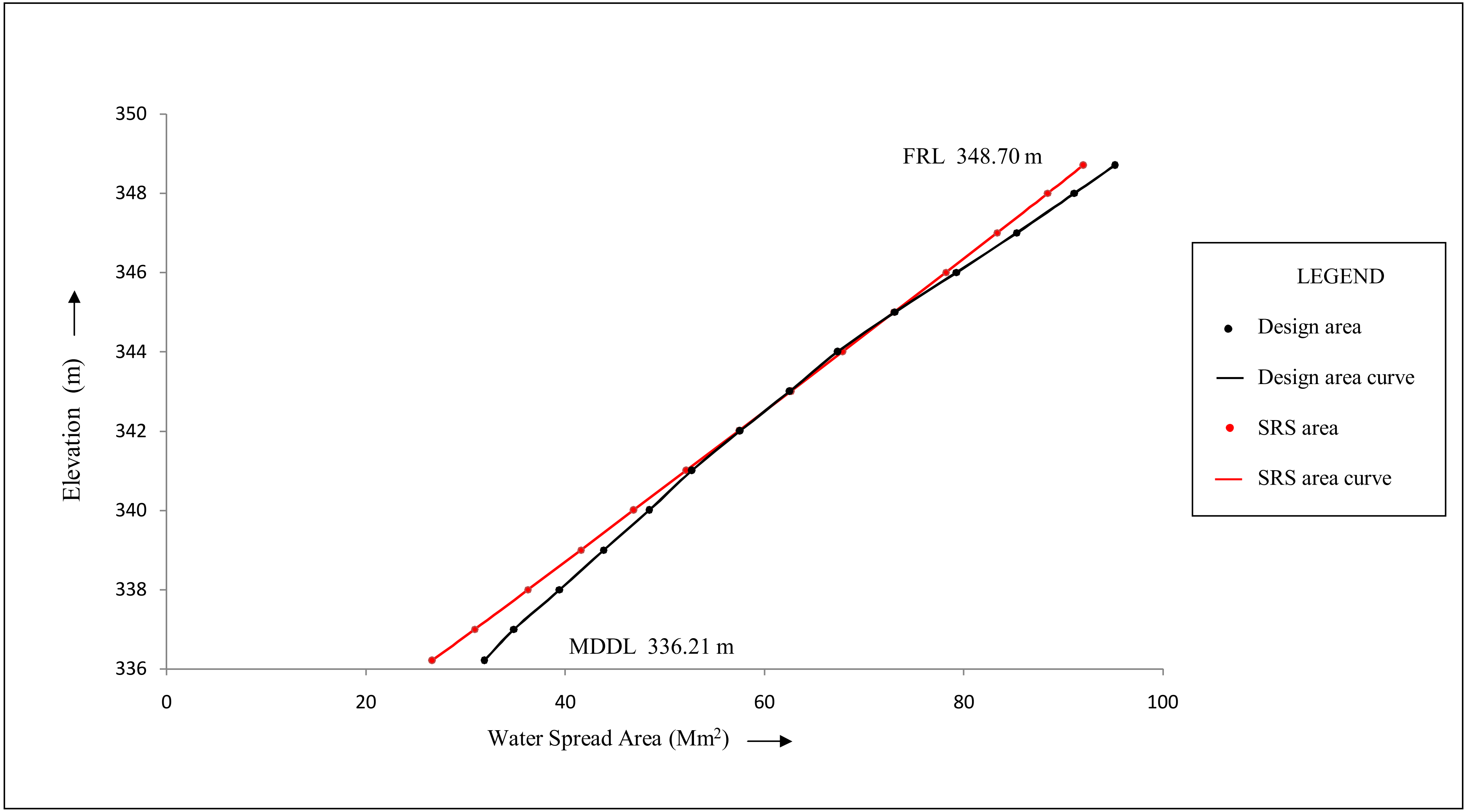

Figure 9 : Elevation – area curve for different years for Ravishankar Sagar reservoir, Chhattisgarh

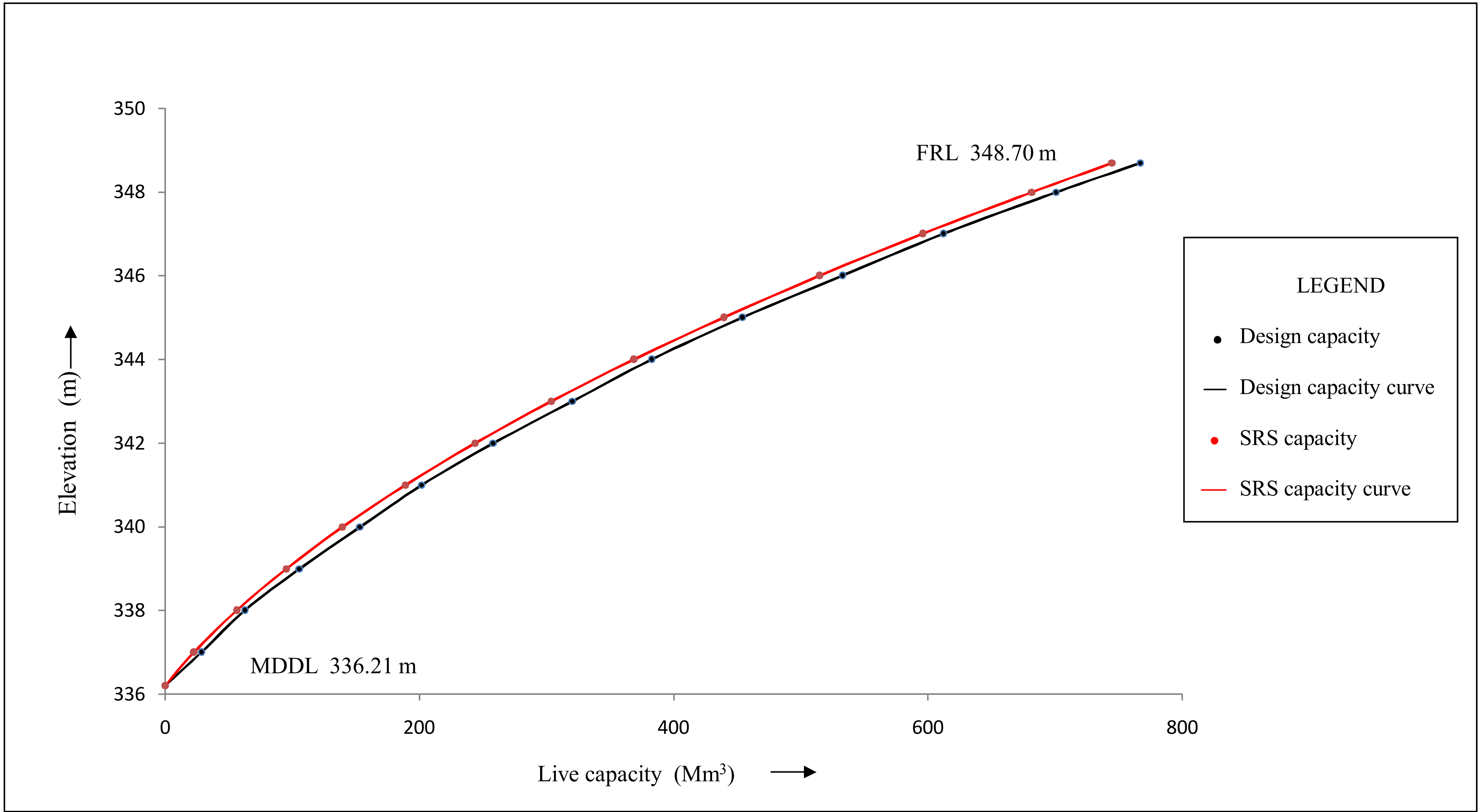

Figure 10 : Elevation – capacity curve for different years for Ravishankar Sagar reservoir, Chhattisgarh

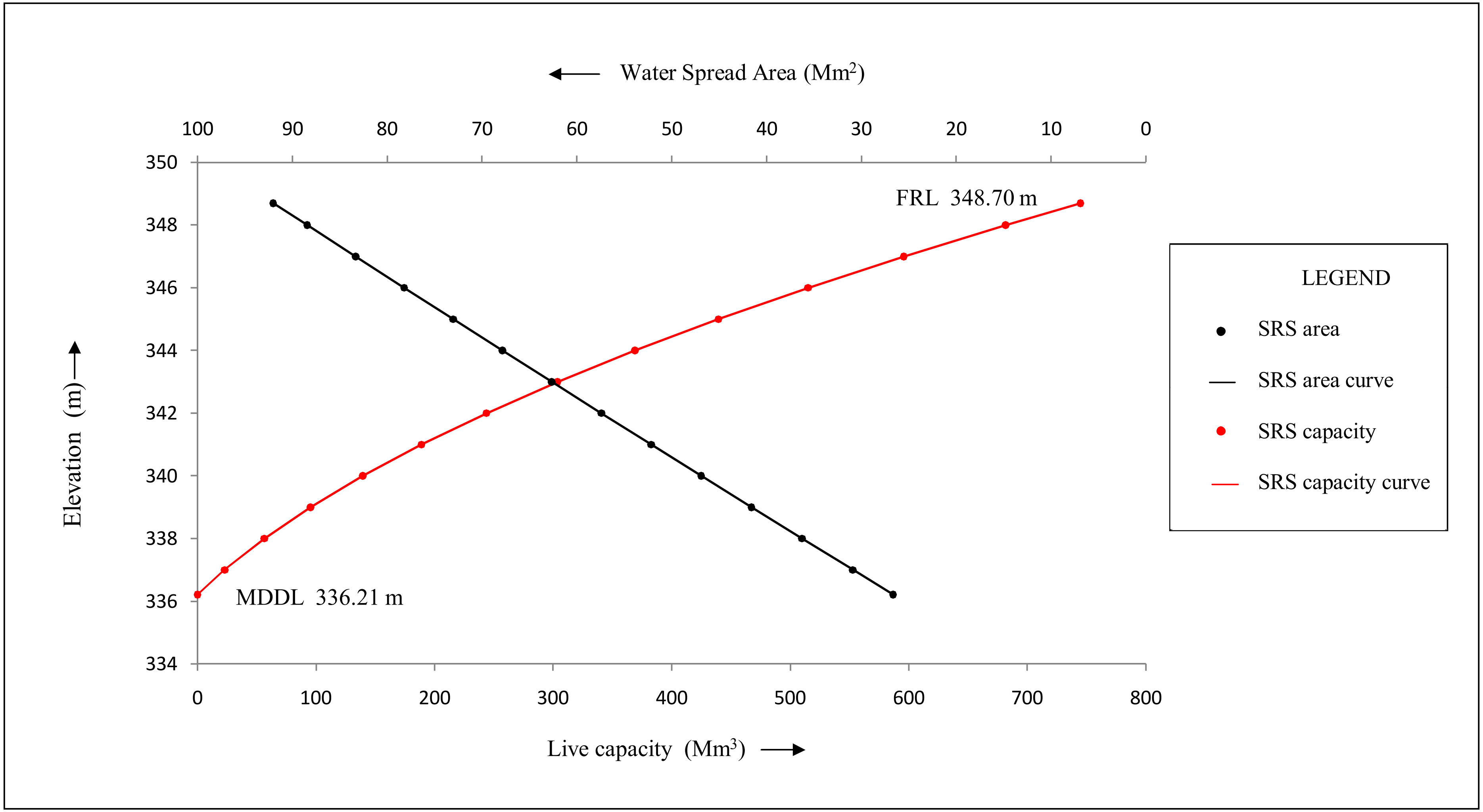

Figure 11 SRS elevation – area - capacity curve for Ravishankar Sagar reservoir, Chhattisgarh

10.8 Comparison with earlier surveys

The comparison of water spread area obtained through remote sensing analysis with original surveyed data is given in Table 7.

Table 7 : Comparison of water spread areas of reservoir

Water elevation (m)	Original survey 1979 (Mm^2)	SRS survey 2013-14 (Mm^2)
MDDL 336.21	31.878	26.660
337.00	34.863	30.905
338.00	39.442	36.257
339.00	43.834	41.585
340.00	48.414	46.889
341.00	52.728	52.169
342.00	57.558	57.425
343.00	62.546	62.657
344.00	67.354	67.865
345.00	73.103	73.049
346.00	79.281	78.209
347.00	85.313	83.345
348.00	91.109	88.458
FRL 348.70	95.176	92.022

The comparison of present live storage capacity with original capacity is given in Table 8.

Table 8 : Comparison of live storage capacity of reservoir

Water elevation (m)	Original survey 1979 (Mm^3)	SRS survey 2013-14 (Mm^3)
MDDL 336.21	0.000	0.000
337.00	28.530	22.718
338.00	62.740	56.263
339.00	105.680	95.154
340.00	153.340	139.364
341.00	201.490	188.870
342.00	258.150	243.646
343.00	320.430	303.668
344.00	382.570	368.911
345.00	454.190	439.352
346.00	532.720	514.967
347.00	612.110	595.730
348.00	700.660	681.619
FRL 348.70	766.900	744.783

10.9 Live capacity loss due to sedimentation

Table 9 shows the live capacity loss due to sedimentation between different years.

Table 9 : Live capacity loss due to sedimentation

Details	Original survey 1979	SRS survey 2013-14
Live capacity in Mm^3 (FRL to MDDL)	766.900	744.783
Sediment deposited between two consecutive surveys Mm^3	-	22.117
Period in years since 1st impoundment year 1979	-	34
Rate of sediment deposited between two consecutive surveys Mm^3/year	-	0.65
% loss of live capacity to original live capacity	-	2.88

It is noticed that in comparison to the original capacity of year 1979, there is a loss of live capacity of 2.88 %.

10.10 Field visit and ground truth

Field visit of the reservoir area has been carried out on 4th March 2016 for ground truth verification. Some predetermined ground truth points marked on the satellite image printouts along with their latitude and longitude values have been verified, with the help of GPS (Trimble Juno) receiver. Following officers were present during this field visit.

Officers from Resources Engineering Center, MERI, Nashik

i) Shri. M. M. Kulkarni, Assistant Engineer Gr.I

ii) Shri. S. G. Wagh, Assistant Engineer Gr.II

iii) Shri. D. R. Nikam, Sectional Engineer

Team from Musi Project

i) Shri. S. K. Netam, Sub-divisional officer
(Water Management Sub-Division No.9, Gangrel)

ii) Shri. S. K. Nagchoudhary, Sub- Engineer

iii) Miss. Jagrati Sahu, Sub- Engineer

iv) Shri. P. K. Khetrapal, Sub- Engineer

Latitude and Longitude values of the reservoir components have been recorded during the field visit. Reservoir levels used in the present analysis have been confirmed in field visit. The reservoir level on the day of visit was observed as 342.83 m. The Photographs of ground truth scenario are shown in Annexure III.

11. Results and Discussions

The summary of the result of sedimentation study of Ravishankar Sagar reservoir is shown in Table 10.

Table 10 - Summary of results

Details	Original survey 1979	SRS survey 2013
Live capacity in Mm^3	766.900	744.783
Catchment area – sq km	3670	
Cumulative loss in live capacity in Mm^3	-	22.117
Cumulative % loss	-	2.88
No. of years	-	34
Annual % loss	-	0.08

The following observations are recorded from present study.

- Present live capacity (year 2013-14) of Ravishankar Sagar reservoir is found as 744.783 Mm^3. Modified SRS elevation-area-capacity values are given in Table 6 and represented in Figure 11.

12. Limitations

The sedimentation survey using Remote Sensing Technique has following limitations

- The remote sensing based capacity estimation works between the operating levels i.e. MDDL to FRL only. Thus changes can be estimated only in live capacity of reservoir.
- The cloud free satellite data throughout reservoir operation in single year is not possible. As such data from different years are selected.
- General error can creep in the identification of tail end of reservoir, particularly in the rainy season. Reservoir authorities have been consulted to remove this ambiguity.

13. Conclusions

Following conclusions can be drawn from the study:

- The live storage capacity of Ravishankar Sagar reservoir is 744.783 Mm^3 in year 2013-14.
- Capacity loss of 2.88 % in live storage is observed in a period of 34 years since original survey in 1979.
- Annual live capacity loss works out to 0.08 %.

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Varshney, R.S., (1997), Impact of siltation on the useful life of large reservoirs, State of art report of INCOH, No. INCOH/SAR-11/97, NIH, Roorkee.

Annexure I

Salient Features

1	Name of Project	:	Ravishankar Sagar Project	
2	Purpose	:	Irrigation	
3	River	:	Mahanadi river	
4	Location Near village	:	Gangrel	
	Taluka	:	Dhamtari	
	District	:	Dhamtari	
	State	:	Chhattisgarh	
	Latitude	:	20^0 37' 00" N	
	Longitude	:	81^0 34' 00" E	
5	Catchment area	:	3670 sq km	
6	Mean annual runoff	:	1651 Mm^3	
7	Year of completion	:	1979	
8	Reservoir details	:		
	i) Type of dam	:	Earthen Dam	Rock fill Dam
	ii) Total length of dam	:	1245.75 m	130.00 m
	iii) Max height of dam	:	33.50 m	10.00 m
9	Control levels	:		
	Top Bund Level (TBL)	:	353.00 m	
	Max. Water Level (MWL)	:	350.70 m	
	Full Reservoir Level (FRL)	:	348.70 m	
	Minimum Draw Down Level (MDDL)	:	336.21 m	
10	Reservoir capacity (Design)	:		
	i) Gross storage at FRL	:	910.50 Mm^3	
	ii) Gross storage at MDDL	:	143.60 Mm^3	
	iii) Live storage capacity	:	766.90 Mm^3	
11	Spillway details			
a)	Maximum discharge	:	17,230 m^3/s	
	i) Radial crest gates	:	14 Nos. - 15 m x 10 m	
	ii) Stoplog gates	:	2 Sets each comprising of one non-interchangeable bottom pieces of size 15 m x 2.112 m and 4 no. interchangeable bottom pieces of size 15 m x 2.112 m	
	iii) Feder canal regulator	:	4 no. (1.8 m x 1.2 m)	

b)	Feeder canal		
	i) Length	:	42 km
	ii) Head discharge	:	19.83 m^3/s
c)	Power		
	i) No. and size of units	:	4 no. of 2.5 MW
	ii) Types of turbines	:	propeller standard type turbine
	iii) Capacity	:	2.5 MW x 4 no. = 10 MW

Reservoir Levels Pertaining to Cloud Free Satellite Data

Path/Row – 102 / 58 | Design gross storage at FRL – 910.50 Mm^3

FRL – 348.70 m, | Design live storage – 766.90 Mm^3

MDDL – 336.21 m | Dead storage – 143.60 Mm^3

Date of pass	**Reservoir level (m)**	**Capacity covered (Mm^3)**
1	2	4
02 Dec 2013	348.69	909.54
24 Feb 2014	347.38	785.64
01 Apr 2014	345.93	670.77
01 Mar 2013	344.14	534.95
25 Apr 2014	343.33	484.22
07 May 2014	342.73	447.21
31 May 2014	341.55	373.94
30 Apr 2013	340.16	304.73
24 May 2013	338.42	221.01
Variation in capacity		(909.54 – 221.01) = 688.53
% variation of live storage		(688.53 / 766.90) × 100 = 89.78 %

Ground Truth Scenario

Spillway upstream

Spillway downstream

Sediment in submergence

Vegetation in submergence

Water spread

Canal and pump house

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Publication Reg. No: CWC/2022/10