# उपग्रह दूरस्थ संवेदन द्वारा
# तान्दुला जलाशय, छत्तीसगढ का अवसादन आंकलन

# SEDIMENTATION ASSESSMENT OF TANDULA RESERVOIR, CHHATTISGARH, THROUGH SATELLITE REMOTE SENSING

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केन्द्रीय जल आयोग
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दूरस्थ संवेदन निदेशालय

**Government of India**
**Central Water Commission**
**Environment Management Organization**
**Remote Sensing Directorate**

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# SEDIMENTATION ASSESSMENT OF
# TANDULA RESERVOIR,
# CHHATTISGARH, THROUGH SATELLITE REMOTE SENSING

**Year of Survey 2018**
**Data Used 2015- 2016**

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# EXECUTIVE SUMMARY

The dynamic aspects of the reservoir, mainly water spread, suspended sediment distribution and concentration requires periodical mapping and monitoring. Sedimentation in a reservoir has a bearing on the capacity of the reservoir as it affects both live and dead storages. In other words, the life of a reservoir depends on the rate of siltation. The satellite data provides opportunity to study these aspects on various scales and at different stages. The present report comprises of use of satellite remotely sensed data for the years 2015-16 in the sedimentation study of Tandula reservoir. The various aspects of the reservoir sedimentation, like the process of sedimentation in the reservoir, sources of sediment, measures to check the sediment and limitations of space technology have been discussed in the report.

Multi-date satellite remote sensing data provide information on elevation contours in the form of water-spread area. Any reduction in reservoir water spread area at a specified elevation corresponding to the date of satellite data is indicative of sediment deposition. The quantity of sediment load settled down over a period of time can thus be determined by evaluating the change in the aerial spread of the reservoir at various elevations.

The original gross and live storage capacities were 312.18 MCM & 302.31 MCM respectively. After analysis of the satellite data in the present study, it is found that live capacity of the Tandula reservoir in 2016 is 293.20 MCM witnessing a loss of 9.11 MCM (i.e. 3.01 %) in a period of 96 years during 1920 to 2016. This accounts for live capacity loss of 0.031% per annum since 1920.

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# ABBREVIATIONS

| | |
|---|---|
| CWC | Central Water Commission |
| DSL | Dead Storage Level |
| FCC | False Colour Composite |
| FRL | Full Reservoir Level |
| IRS | Indian Remote Sensing |
| LISS | Linear Imaging Self Scanner |
| MDDL | Minimum Draw Down Level |
| MSL | Mean Sea Level |
| MWL | Maximum Water Level |
| NIR | Near Infra-Red |
| NRSC | National Remote Sensing Centre |
| SRS | Satellite Remote Sensing |
| N.A. | Not Available |
| NDVI | Normalised Difference Vegetation Index |
| WSA | Water Spread Area |

# UNITS USED

| | |
|---|---|
| cumec | cubic metre per second |
| m | Metre |
| million $m^2$ | million square metre |
| million $m^3$ /MCM | million cubic metre |
| ha | Hectare |
| Sq Km | Square Kilometre |
| mm/year | millimetre per year |

# SEDIMENTATION ASSESSMENT OF TANDULA RESERVOIR, CHHATTISGARH THROUGH SATELLITE REMOTE SENSING

## 1 INTRODUCTION

India – the second largest country in the world in terms of population – has about 17% of world's population, about 4% of world's water resources, and 2.5% of total geographical land area of the world. Therefore, in spite of having an average annual average precipitation to the tune of more than 1100 mm/year, the population density (lack of land resources) and per capita water resources availability make India a water-stressed country, as a whole. However, at a regional or basin level, many areas in the country are water-scarce or severely water-scarce owing to the spatial and temporal variability of water resources.

It is estimated that average annual precipitation over India is about 4000 BCM. Out of this precipitation, the average annual water resources availability of the country is about 1869 BCM, as estimated by Central Water Commission (CWC) in 1993. The water resources availability situation gets more murkier due to topographical and other constraints. Due to this, the total utilisable water resources in the country are about 1137 BCM (690 BCM of surface water and 447 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, urbanisation 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%) is available in these three months only in rivers. Therefore, in order to sustain life and other activities throughout the year from a resources that is 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. Realising the importance of storage structures, a large number of reservoirs have been built, since independence, during each plan on almost all river basins, except Ganga and Brahmaputra, to tap the available surface water and to utilize it as and 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.

Correct assessment of the sedimentation rate is essential for assessing useful life of the reservoir as well as optimum reservoir operation schedule. Since 1958, when it was established that the live storage of reservoir is getting reduced due to siltation, a systematic effort has been made by various departments / organizations to evaluate the capacity of reservoirs. Various techniques like boat echo sounder, etc. being replaced by hydrographic data acquisition system (HYDAC) and HITECH method using Differential Global Positioning System (DGPS). The conventional techniques are found either time consuming or costly and require considerable manpower. Remote sensing technique to calculate the present live capacity of 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 Tandula reservoir, Chhattisgarh by Central Water Commission, New Delhi.

## 2. SOURCES AND MECHANISM OF SEDIMENTATION

The principal sources of sediments are as follows:

1. Deforestation
2. Excessive erosion in the catchment
3. Disposal of industrial and public wastes
4. Farming
5. Channelisation works
6. Human activities
7. Land development, highways, and mining

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 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 the erosion. Sediment transportation depends upon slope of the catchment, channel geometry and nature of riverbank 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.

In order to obtain the knowledge of sedimentation in the reservoir, it is necessary to study the mechanism of sedimentation, which will help to mitigate reservoir sedimentation, prolong the life span of reservoirs and to take full benefits of reservoirs. The sediment deposition in a reservoir depends on the following:

Longitudinal and lateral valley shape
Length and shape of reservoir
Flow patterns in reservoir
Capacity to inflow volume ratio (trap efficiency)
Grain size distribution of sediment
Water and sediment discharges
Mode of reservoir operation
Nature of incoming floods

Characteristics of reservoir sedimentation include amount, distribution, configuration and composition of reservoir 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 the influence of gravity (Fig. 1). 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, a fluid under, over, or through a fluid or fluids of approximately equal density. From Fig. 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, 1997).

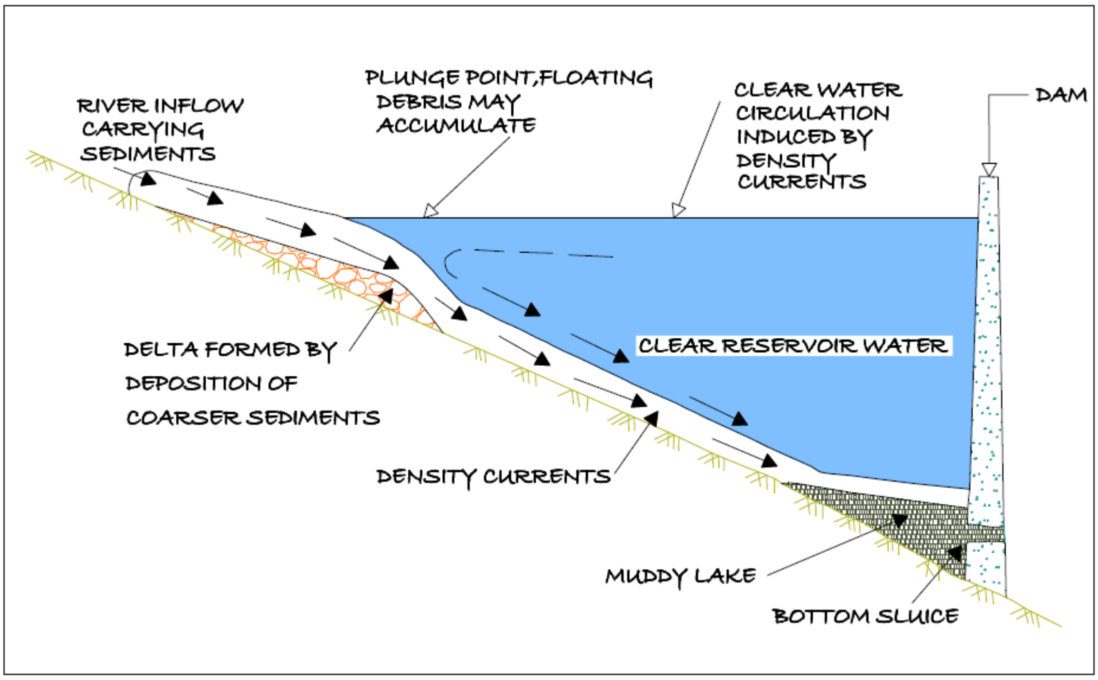



**Fig. 1: Conceptual sketch of density currents in a reservoir**

The magnitudes of these relative change and their effects upon sediments deposition depend on many factors such as reservoir shape, channel slopes, relation of outflow to inflow and density differences. As a rule, however, conditions are such that density currents move very slowly. In many respects deposits in a reservoir resemble those in a delta, made by stream where it discharges into a lake or sea. The deposits are (i) bottom set beds consisting of the fine sediments brought in by the stream, (ii) the forest beds formed of the coarser sandy sediments, (iii) top set beds consisting of coarser particles and (iv) density current deposits.

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 depth. It is now fully realized that deposition takes place throughout the reservoir reducing the incremental capacity at all elevations.
Longitudinal deposition patterns in the reservoir will vary from one reservoir to another as influenced by pool geometry, discharge and grain size characteristic of the inflowing load and reservoir operation. There can be four types of depositing patterns in the reservoir as shown in the fig 2.

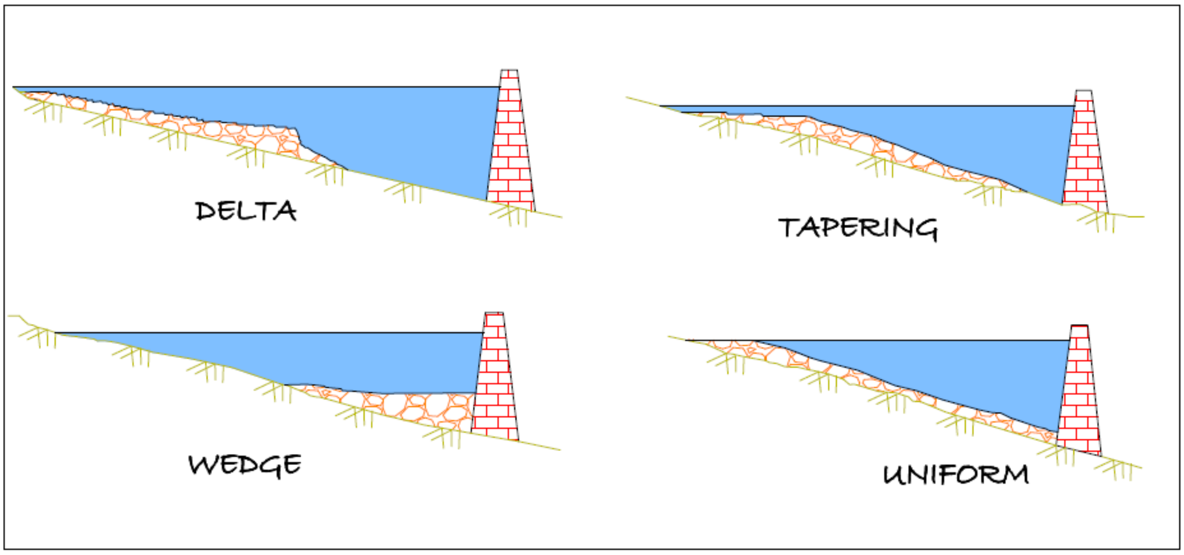



**Fig. 2: Longitudinal Patterns of sediment deposition in reservoirs.**

Delta deposits contain the coarsest fraction of the sediment load, which is rapidly deposited at the zone of inflow. It may consist entirely of coarse sediment or may also contain a large fraction of finer sediment such as silt. Wedge-shaped deposits are thickest at the dam and become thinner moving upstream.

This pattern is typically caused by the transport of fine sediment to the dam by turbidity currents. Wedge- shaped deposits are also found in small reservoirs with a large inflow of fine sediment, and in large reservoirs operated at low water level during flood events, which causes most sediment to be carried into the vicinity of the dam. Tapering deposits occur when deposits become progressively thinner moving toward the dam. This is a common pattern in long reservoirs normally held at high pool level, and reflects the progressive deposition of fines from the water moving toward the dam. Uniform deposits are unusual but do occur. Narrow reservoirs with frequent water level function and small load of fine sediment can produce nearly uniform deposition depths. Several factors like amount of sediment load, size distribution, fluctuations in stream discharge, shape of reservoir, stream valley slope, vegetation at the head of the reservoir, location and size of reservoir, outlets, etc., control the location of sediment deposits in the reservoir.

Figure 3 shows different levels in the reservoir where-in the capacity is affected. Reservoirs operate between Minimum Draw Down Level (MDDL), which is at sluice level to Full Reservoir Level (FRL), which is at dam level. The storage between these two levels is the live storage as shown in Fig. 3. The storage below MDDL is the dead storage. Water stored along the valley bed is known as valley storage.

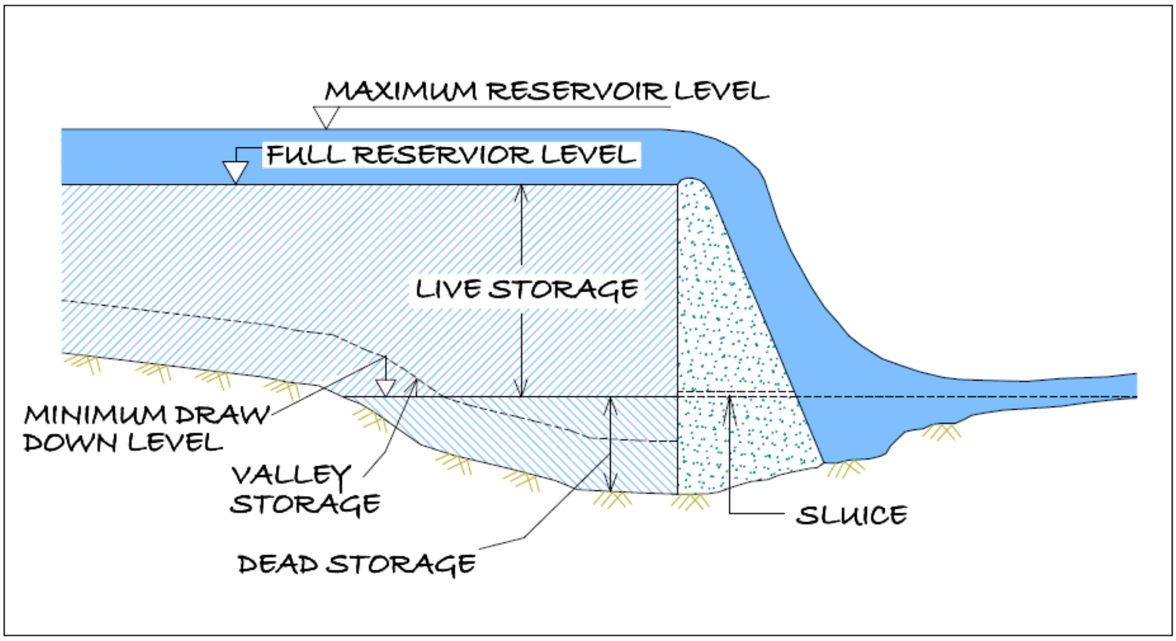



**Fig. 3: Conceptual sketch of different levels in a reservoir**

## 3. CONTROL OF SEDIMENTATION

Due to the multiple variables involved in reservoir sedimentation, no single control measure can be considered as the most effective. The measures, which can be employed to limit sedimentation and turbidity, are as under:

1. Soil and water conservation measures within the drainage basin, contour ploughing, strip cropping, suitable farming practices, improvement of agricultural land, construction of small dams/ponds/terraces/check dams on

gullies

2. Revetment and vegetation cover
3. Evacuation of sediment
4. Reservoir shoreline protection
5. Stream bank and flood plain protection
6. Ridge plantation such as pasture development and reservoir shoreline protection

Silting not only occurs in the dead storage but also encroaches into the live storage zone, which impairs the intended benefits from the reservoirs. Therefore, the problem of sedimentation needs careful consideration. Adequate provision has to be made in the reservoir for accumulation of anticipated quantities of silt. Steps are also required to be taken to ensure that the storage capacities available are not lost or get reduced by accelerated sedimentation.

## 4. 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 sensor on-board satellite and then are transmitted back to earth. Difference between features depends on the fact that 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.

The data from satellites such as Landsat, SPOT and IRS are more useful for mapping and monitoring the surface water bodies and other land resources based on which, better water management strategies could be planned. Water is one of the most easily delineable features on the satellite data due to high contrast between land and water bodies in NIR band. Water absorbs all the incident energy in NIR region depending upon nature and status of water body. Land features reflect more energy in NIR region. The Fig. 4 shows the reflectance curves for clear and turbid water categories.

Spectral response of water is affected by variables like time of the year, sun elevation angle, water vapour content in the atmosphere, roughness of water surface, water colour, turbidity, type and concentration of suspended particles, depth of water, characteristics of bottom material and submerged or emergent vegetation.

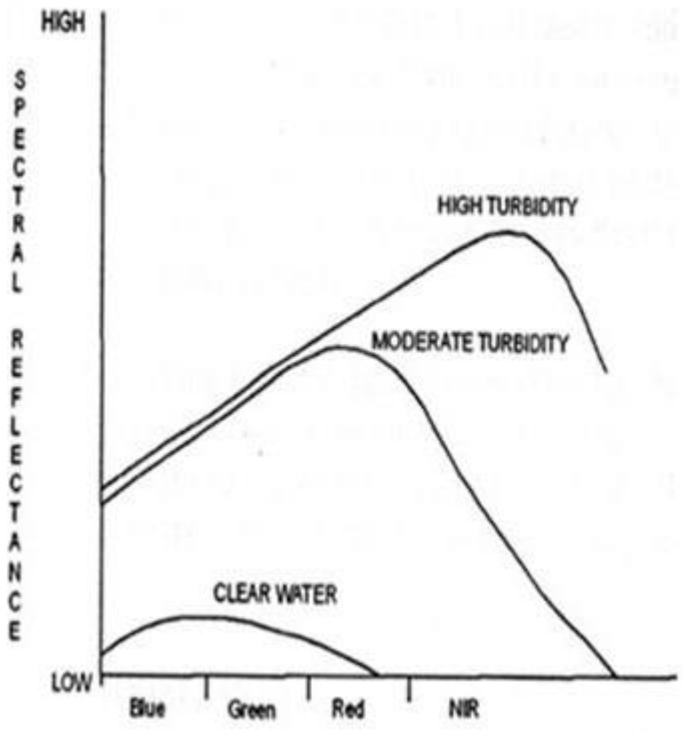



**Fig. 4: Reflectance curves for Clear and Turbid water**

Reservoir sedimentation surveys are essentially based on mapping of water-spread area at the time of satellite over pass. Multi-date satellite data is needed which covers the operating level of reservoir at close interval. Water spread area is nothing but water level contour at that level. Using different contours, capacity between them is calculated. With the sedimentation, the water spread area of the reservoir reduces at different levels. The water spread area and the elevation information is 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 the change in capacity between different levels.

Remote Sensing based reservoir capacity estimation has certain limitations. The capacity estimation works between MDDL and FRL only as these are the levels between which reservoir operates. Thus changes can be estimated only in live capacity of reservoir. For capacity estimation below MDDL corresponding to dead storage other methods like hydrographic survey are to be used. Availability of cloud free data throughout reservoir operations also poses limitation in the analysis. This is overcome by combining data from different water years to get full operative range. This technique gives accurate estimates for fan shaped reservoir where there is a considerable change in water spread area with change in water level.

## 5. OBJECTIVES

The objective of the study is to estimate live capacity loss of Tandula reservoir due to sedimentation through Satellite Remote Sensing. Following objectives will be achieved in the study.

a. Updation of Elevation - Area - Capacity curve using satellite data in live storage zone.

b. Estimation of storage loss due to Sedimentation

## 6. STUDY AREA

Tandula dam is located in Balod tehsil of Durg district, Chhattisgarh at about 5 km from the Balod city. The dam was completed on the confluence of Sukha Nala and Tandula River in 1920, with a catchment area of 818 Sq.km. The dam is 3819.6m long and 25.02m in height. The gross, live and dead storage capacities of the reservoir are 312.18 MCM, 302.31 MCM and 9.87 MCM respectively. For the reservoir, the highest flood level, the FRL, and MDDL are 333.40 m, 332.20 m, and 320.45 m. Salient features of Tandula reservoir as displayed on site is shown in fig. 5 and Index map of Tandula Reservoir is shown in fig. 6.


**Fig. 5: Salient features of Tandula Reservoir as displayed on site [2]**

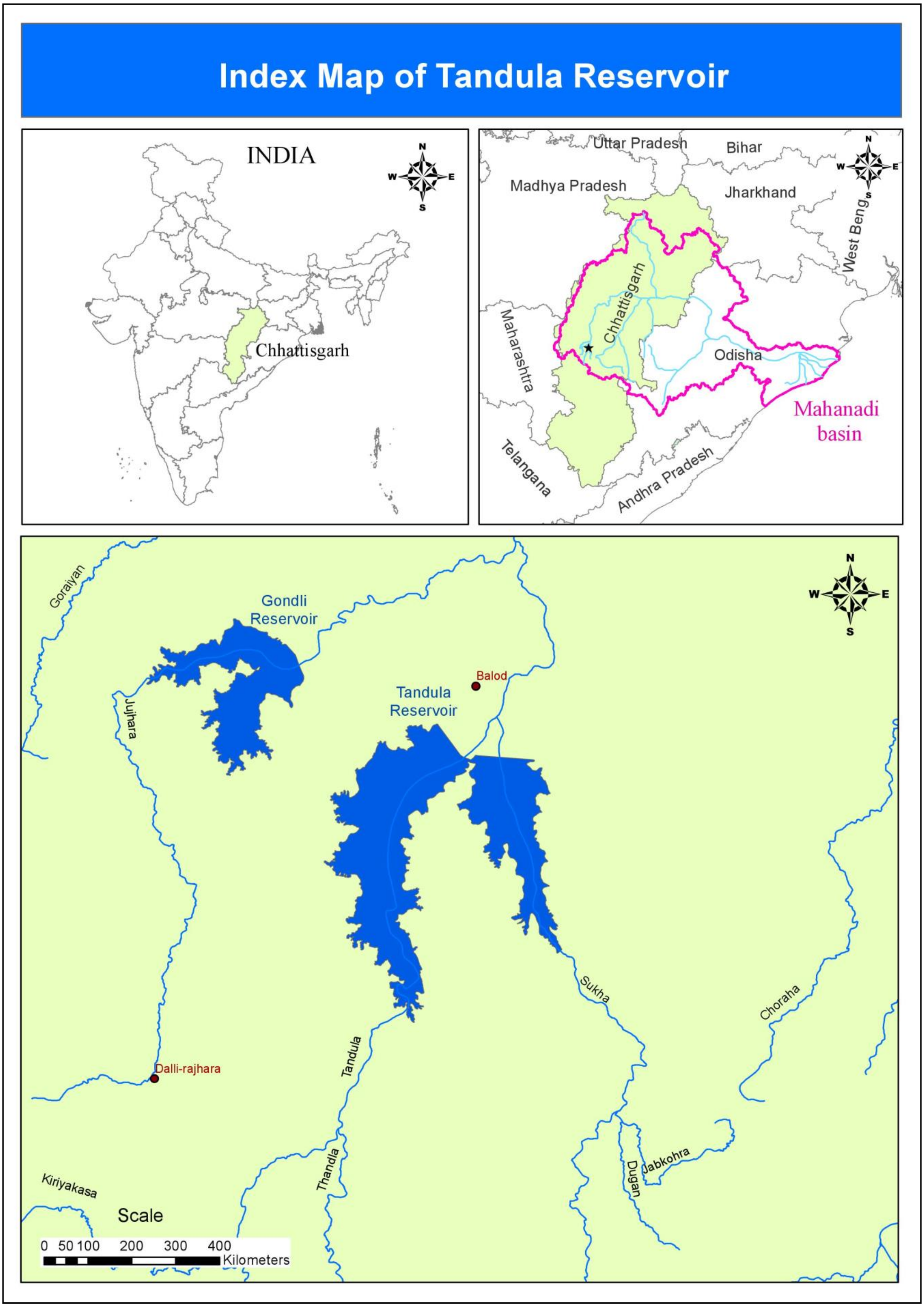



**Fig. 6: Index map of the Tandula Reservoir**

## 7. APPROACH FOR PRESENT STUDY

Remote Sensing technique makes use of water-spread of the reservoir between maximum and minimum operating level during the observation period. Since the reservoir levels generally do not go below the MDDL, water spread observations are not possible below MDDL. The same are to be extrapolated from observed elevation-area curve to find out capacity below MDDL. In the case of Tandula reservoir, the height difference between FRL (332.20 m) and MDDL (320.45 m) is 11.75 m and the use of satellite remote sensing in the present study has been restricted in live storage.

## 8 DATA USED

### 8.1. SATELLITE DATA

IRS-Resourcesat 2- LISS III and IRS P6- LISS III data for six (06) dates has been used in the analysis. Table 1 depicts the Path and Row index along with date of pass of satellite.

**Table – 1: Date of pass for satellite data**

| Satellite | Path | Row | Date of pass | Elevation (m) |
|---|---|---|---|---|
| IRS-RS2 LISS III | 101 | 57 | 18-OCT-2016 | 331.750 |
| IRS-RS2 LISS III | 102 | 58 | 05-OCT-2015 | 329.490 |
| IRS-P6 LISS III | 101 | 57 | 12-OCT-2015 | 328.460 |
| IRS-RS2 LISS III | 101 | 57 | 24-OCT-2015 | 326.810 |
| IRS-RS2 LISS III | 101 | 57 | 09-MAY-2015 | 324.620 |
| IRS-RS2 LISS III | 102 | 58 | 01-JUN-2016 | 323.580 |

### 8.2. FIELD DATA

The following field data has been obtained from project authorities:

Elevation – Area - Capacity data

Salient features of Tandula reservoir, reservoir levels and capacity data on specified dates

## 9. METHODOLOGY

Digital analysis has an edge over visual analysis in identifying water spread and turbidity levels in detail and more accurately because of minimizing human error or subjectivity. Digital image analysis using Image Processing System on computer mainly, edge enhancement ratios (B/NIR. B/R, R/G), principle component (PC) and classification were found very good for mapping water spread, turbidity levels and surgical aquatic vegetation. For Tandula reservoir studies, multi-date IRS-RS2 LISS III and IRS– P6 LISS III data (06 nos. imageries) is used for the analysis. Image processing with Arc GIS software was used for the analysis. The analysis comprised,

- Geo-referenced Data base.
- Water spread area estimation.
- Estimation of reservoir capacity.
- Comparison with original capacity.

## 9.1. DATA BASE

The satellite data corresponding to reservoir area obtained from NRSC DATA CENTRE was loaded on the system. Bands 2, 3, 4 of the geo-referenced images for all six different dates pertaining to study area were used for further analysis.

## 9.2. WATER SPREAD AREA ESTIMATION

Reduction in capacity of reservoir at different levels is depicted by reduction in water-spread area (WSA) at different water levels. Estimation of water-spread area is done using various digital image processing (DIP) techniques. Various techniques adopted for water-spread area estimation are as follows:

- Generation of False Color Composite (FCC) and analysis of histogram
- Thresholding

### 9.2.1. GENERATION OF FCC AND ANALYSIS OF HISTOGRAM

FCC is generated from three spectral bands of satellite data, generally NIR, Red and Green bands, where water features appear in shades of black and blue depending upon depth and turbidity. Histogram, which is graph between grey values and the frequency of occurrence, is plotted for individual bands. NIR band information is more useful in identification of WSA. The spectral separability between features is more in NIR band. The water pixels are identified and range of grey values is recorded. Under normal conditions when there is no effect of cloud and shadow, water generally occupies lower range of histogram.

### 9.2.2. THRESHOLDING

The areas where clear water/ land demarcation is there, density slicing is successfully used for delineation of water spread areas. Density slicing is a technique where the entire grey values of pixels occurring in the image are divided into a series of analyst specified intervals. All the grey values falling within a range are grouped in one grey value, which is displayed in output. This process divides the image into water and land pixels. From the study of histogram peaks, minimum and maximum value for water pixels is identified and image is then density sliced. Thresholding can be performed on single and or combination of bands. Band ratioing is the technique of enhancing a particular feature or class from the satellite data. Different ratio indices are available to enhance water, vegetation, soil etc. Normalised Difference Vegetation Index (NDVI) is one such index, which enhances vegetation and water.

For estimation of water spread area of Tandula reservoir, use of NDVI has been made. NDVI has been generated using 8-Bit unsigned channel with the help of 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 rationed image is then density sliced. Water pixels generally occupy lower range of histogram in ratioed image.

Water spread areas are extracted for all the scenes. Fig. 8 shows FCC's of different dates and Fig. 9 shows the superimposed reservoir water spreads for different dates. Water spread area has been calculated by multiplying number of pixels with area of each pixel (24m x 24m). Table 2 shows satellite-derived reservoir water spread areas for different satellite overpass dates along with the water levels of the reservoir at the corresponding dates collected from the Office of Engineer-in-Chief, Water Resources Department, Chhattisgarh.

**Table – 2: Water Spread Areas estimated from Satellite Images**

| Date of pass | Elevation (m) | Area (M Sqm) |
|---|---|---|
| 18-Oct-16 | 331.750 | 45.390 |
| 05-Oct-15 | 329.490 | 36.005 |
| 12-Oct-15 | 328.460 | 34.353 |
| 24-Oct-15 | 326.810 | 26.924 |
| 09-May-15 | 324.620 | 18.035 |
| 01-Jun-16 | 323.580 | 15.043 |

### 9.2.3. NDVI ANALYSIS STEP BY STEP:

1. Add images in Band 2,3,4 in ArcMap
2. Stack the bands using Composite bands tool
3. Remove unwanted layers
4. Convert Composite image into FCC image
5. Clip satellite image as per reservoir area approximately
6. Generate NDVI image from FCC image
7. Export NDVI image in output folder
8. Build raster attribute table for NDVI image
9. Picking pixels representing water from image
10. Mark all pixels representing water
11. Reclassify the image using reclassification tool
12. Raster to vector conversion
13. Create AREA field in attribute table
14. Calculate the water spread area using calculate geometry tool

The methodology adopted in this analysis is shown in the flow chart (Fig. 7).

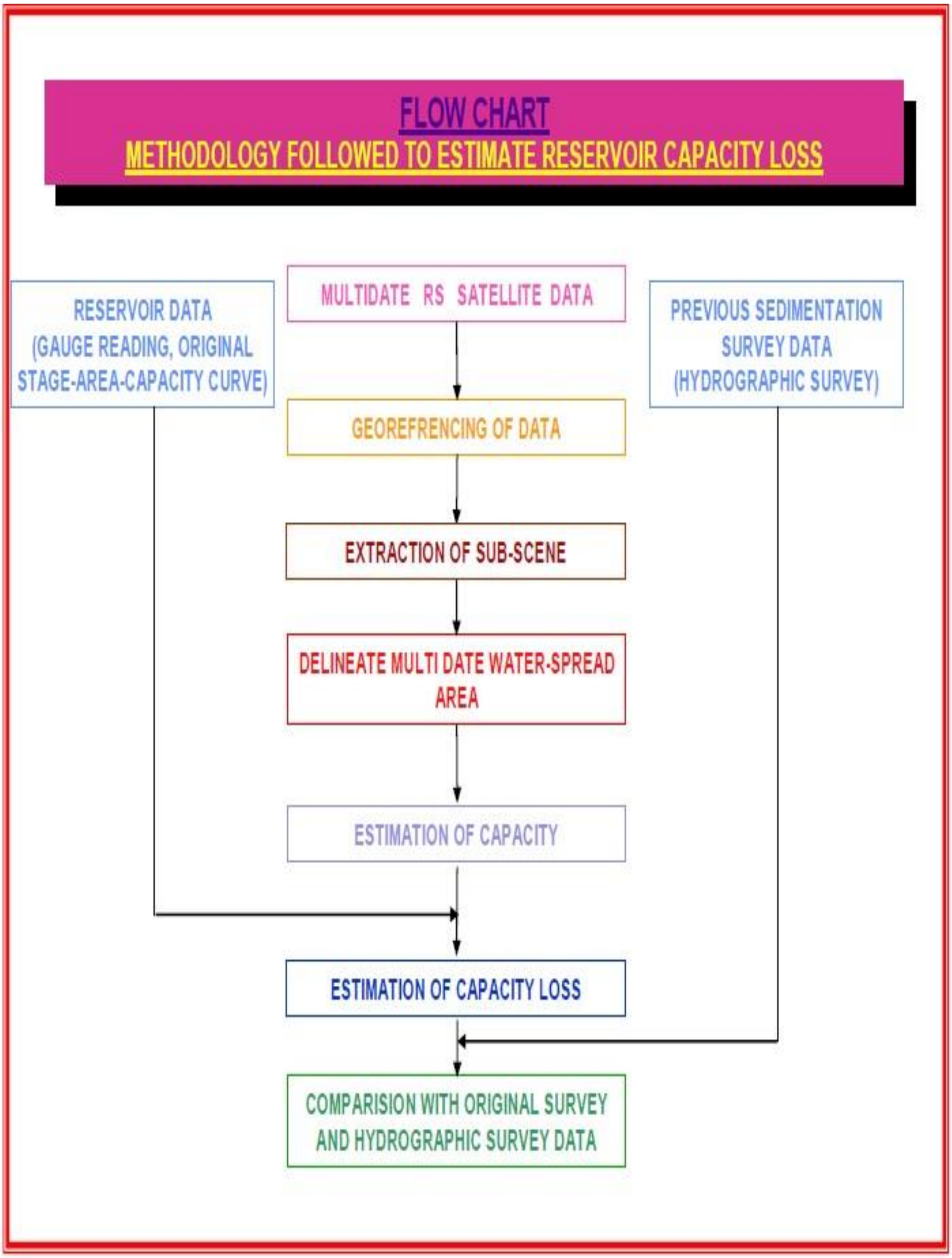
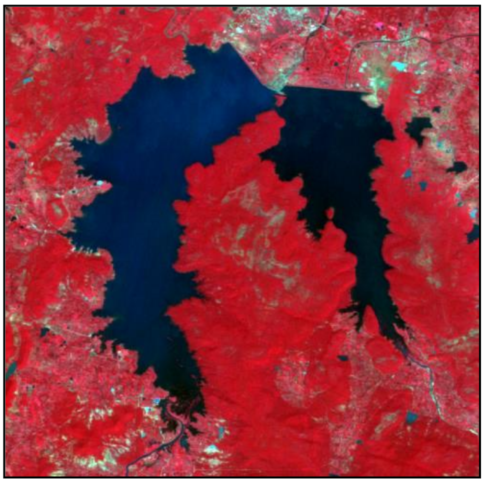
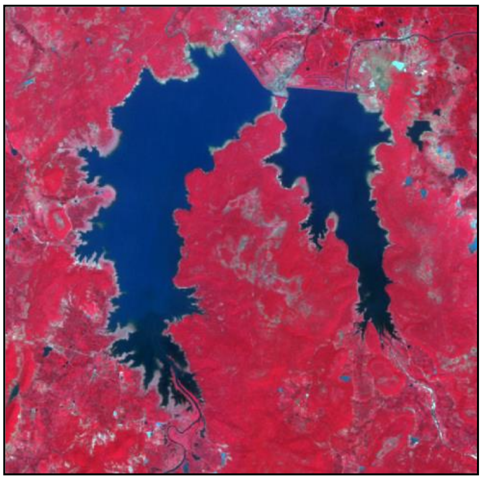


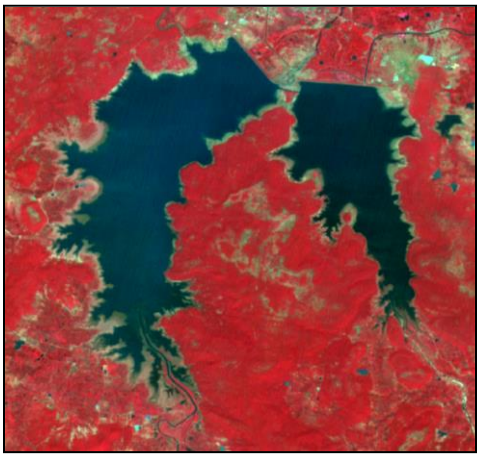

**Fig 7 : Flow chart showing methodology followed to estimate reservoir capacity loss**



**18-Oct-2016 (331.750m)**

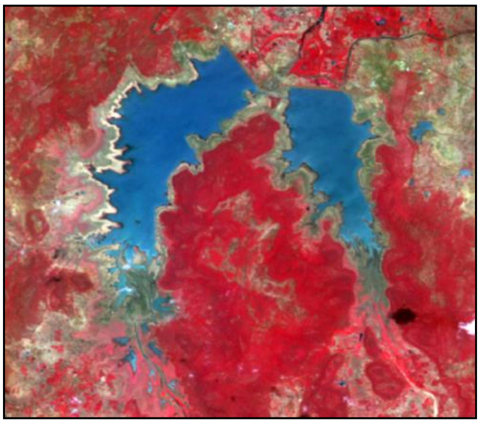


**5-Oct-15 (329.490m)**

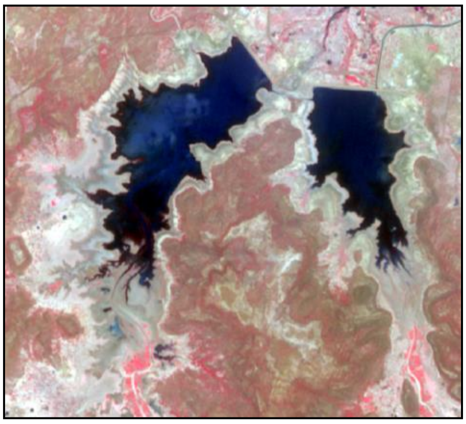


**12-Oct-15 (328.460m)**

**24-Oct-15 (326.810m)**



**9-May-15 (324.620m)**



**01-Jun-2016 (323.580 m)**

**Fig 8 : False Colour Composites(FCCs) showing water spreads at different dates**

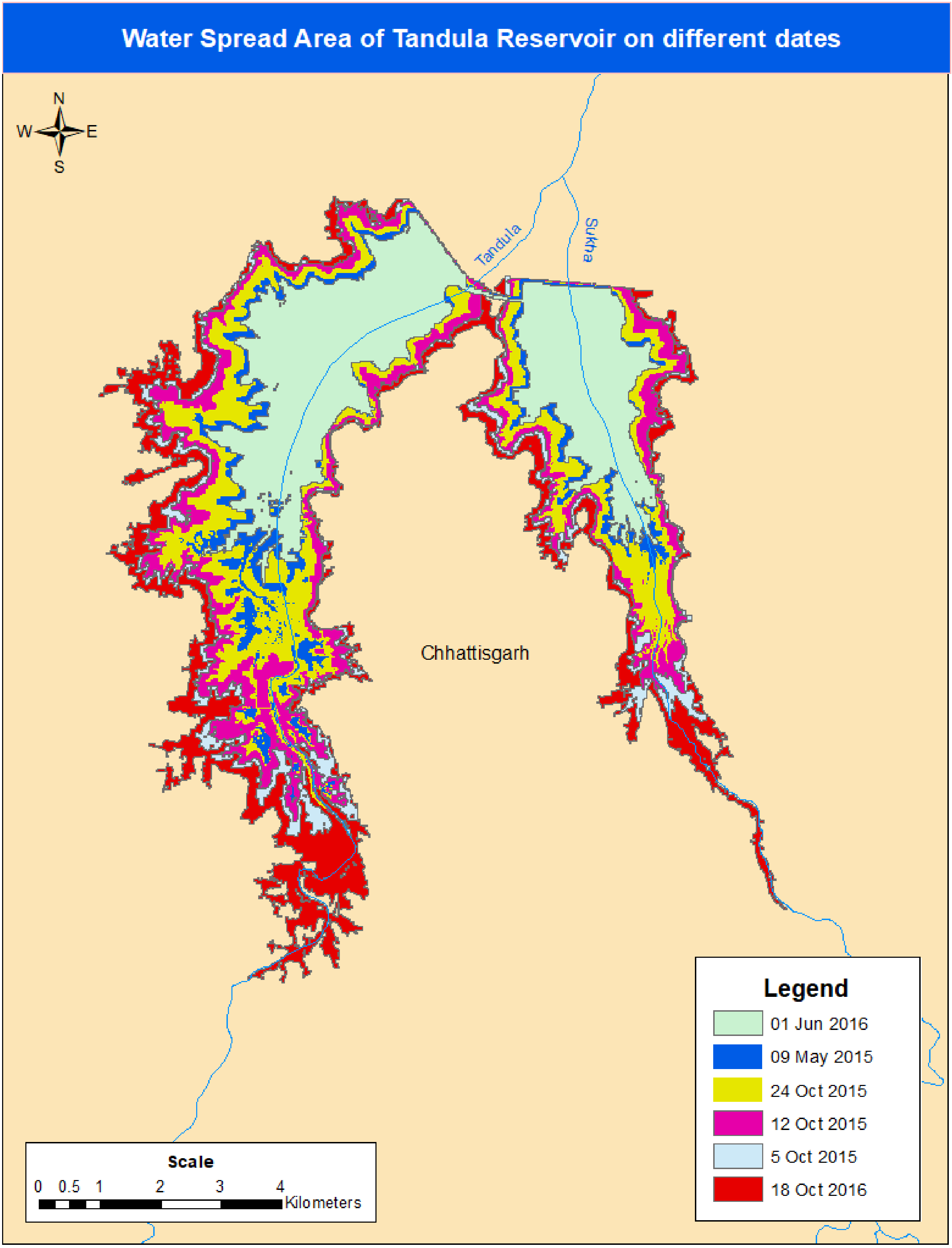



**Fig. 9: Tandula Reservoir Water Spread Area on different dates**

The Satellite Images for the Tandula reservoir have been obtained from NRSC DATA CENTRE. The analysis has been carried out using Digital Image Processing software Arc GIS. The digitally processed images of Tandula Reservoir showing its water spread area for six overpass dates such as 9th May 2015, 24th Oct 2015, 18th Oct 2016, 5th Oct 2015, 1st Jun 2016, 12th Oct 2015 are shown in fig. 9.

The water elevation 331.750m for 18th Oct, 2016 is near the Full Reservoir Level (FRL) of 332.20m and water elevation 323.580m for 01st June, 2016 is well above the Minimum Draw Down Level (MDDL) of 320.45m.

## 9.3. ESTIMATION OF RESERVOIR CAPACITY

Area elevation curve has been plotted using these above six (06) water-spread areas for different water level in the reservoir and a best-fit polynomial equation of second order as given below has been derived.

Y = -0.0144*X^2 +3.9545 * X + 2.4205

$R^2$ = 0.9956

Where X is Elevation in meters

Y is Water Spread Area in M Sqm

Elevation - area curve using this equation has been plotted and shown in Fig-10. Water spread areas derived from satellite data for various dates are also marked on the curve.

Computation of the reservoir capacity at various elevations was made using following formula

V = h/3{A1+A2 + sqrt. (A1*A2)}

Where,

'V' is the reservoir capacity between two successive elevations h1 and h2,

'h' is the elevation difference (h1-h2),

'A1 & A2' are areas of reservoir water spread at elevations h1 & h2.

Table 3 gives the values of Live storage capacity and submergence areas at a regular interval of 1.0 m have been worked out using this best-fit polynomial equation at different elevations.

The Modified live capacity - elevation curve and modified elevation – area –capacity curves are plotted and shown in Fig-11 and Fig-12 respectively.

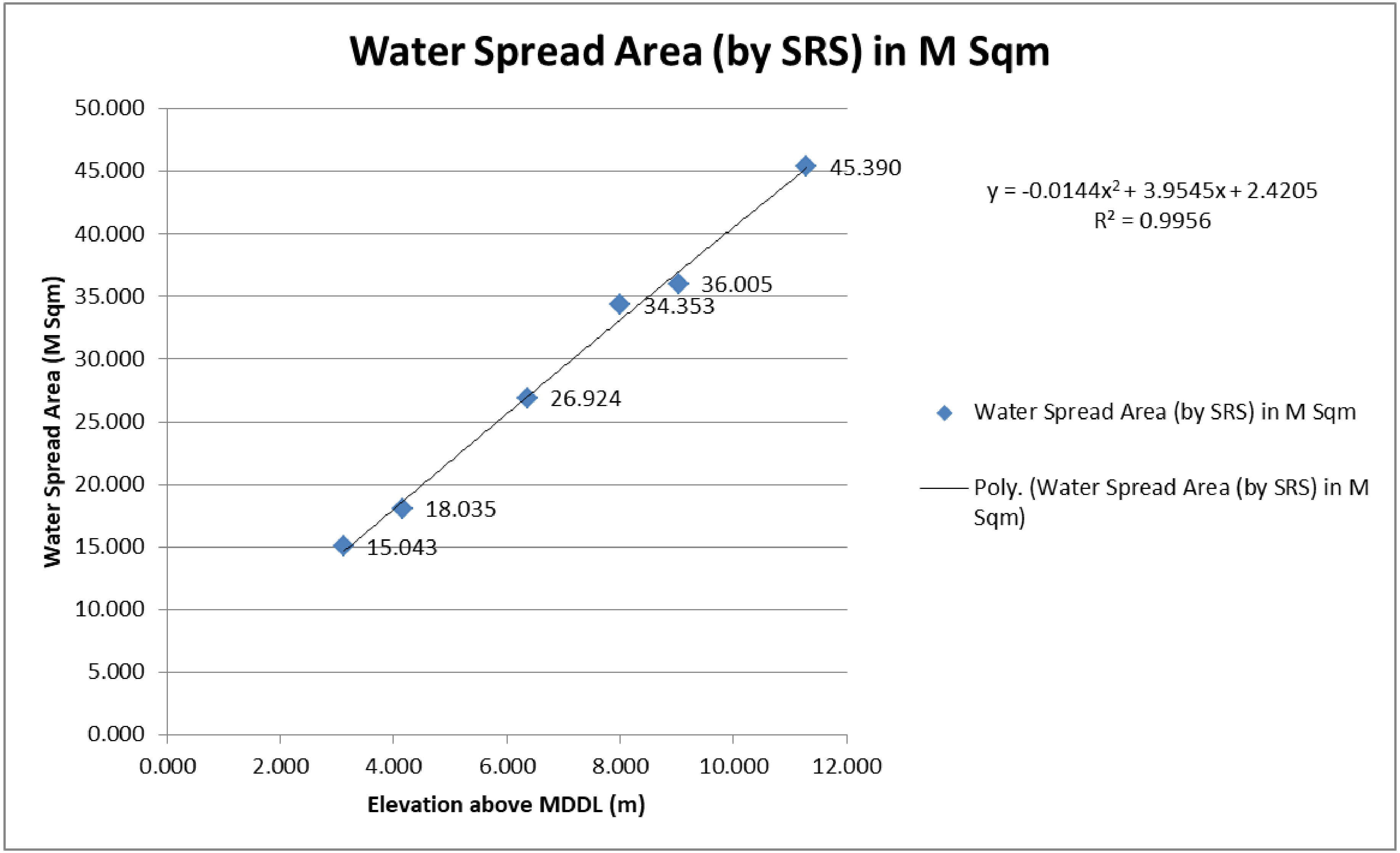



**Fig. 10: Water spread Area of Tandula Reservoir**

**Table-3: Aerial extent of reservoir at regular interval (1.0m) using SRS Survey 2016**

| Reservoir water level in Metre | | Water spread area by trend line (M Sqm) | Segmental Live Capacity (MCM) by SRS technique | Cumulative Live capacity (MCM) by SRS technique |
|---|---|---|---|---|
| **MDDL** | **320.45** | 2.421 | 0 | 0 |
| | 321 | 4.591 | 1.897 | 1.897 |
| | 322 | 8.515 | 6.453 | 8.350 |
| | 323 | 12.411 | 10.402 | 18.752 |
| | 324 | 16.277 | 14.301 | 33.052 |
| | 325 | 20.115 | 18.163 | 51.215 |
| | 326 | 23.924 | 21.992 | 73.207 |
| | 327 | 27.705 | 25.791 | 98.999 |
| | 328 | 31.456 | 29.561 | 128.559 |
| | 329 | 35.179 | 33.300 | 161.859 |
| | 330 | 38.873 | 37.010 | 198.870 |
| | 331 | 42.538 | 40.691 | 239.561 |
| **FRL** | **332.20** | 46.898 | 53.640 | 293.201 |

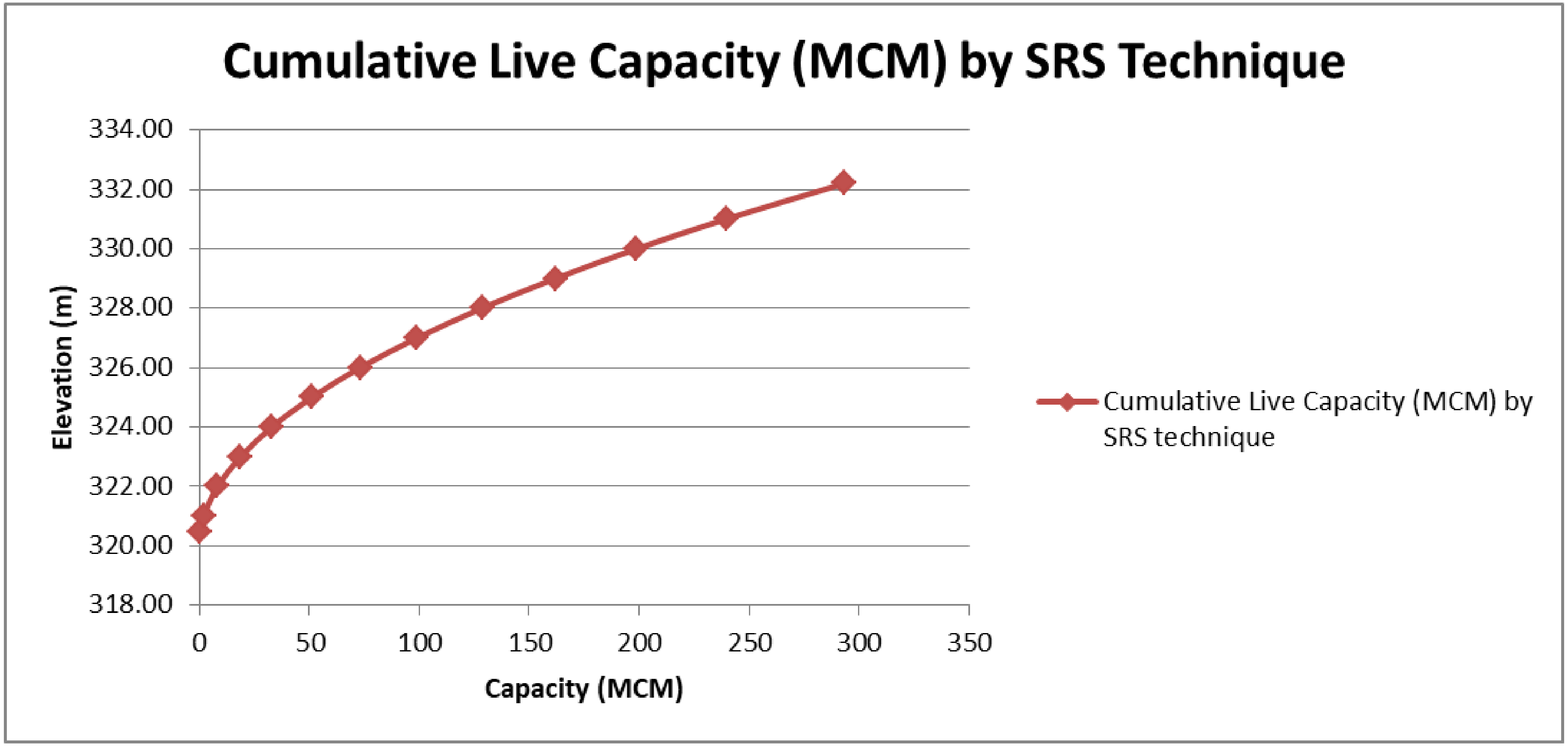



**Fig. 11: Modified live capacity - elevation curve (SRS technique)**

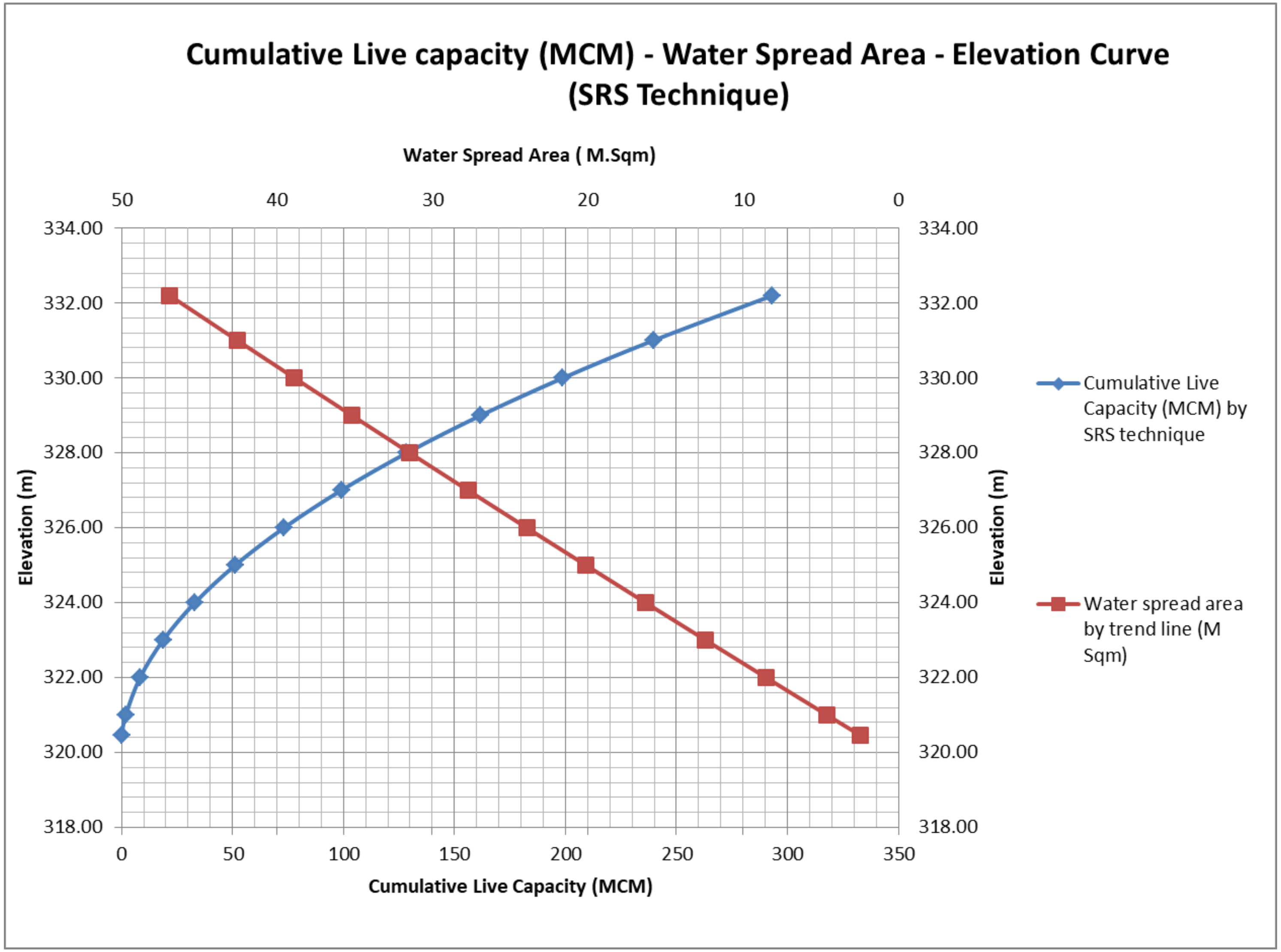



**Fig. 12: Elevation – Area- Capacity Curve**

### 9.4. COMPARISON WITH ORIGINAL SURVEY

Table 4 as given below show the comparison of live storage capacity of SRS survey with original at various elevations respectively. Curve showing comparison of live capacity of SRS survey with original survey is drawn in Fig-13.

**Table -4: Comparison of Live Storage Capacity (MCM)**

| | Elevation (m) | Live Capacity (Original) 1920 (MCM) | Live Capacity (SRS) 2016 (MCM) |
|---|---|---|---|
| **MDDL** | **320.45** | 0.000 | 0.000 |
| | 321.00 | 4.798 | 1.897 |
| | 322.00 | 13.737 | 8.350 |
| | 323.00 | 26.266 | 18.752 |
| | 324.00 | 41.370 | 33.052 |
| | 325.00 | 59.418 | 51.215 |
| | 326.00 | 83.127 | 73.207 |
| | 327.00 | 108.974 | 98.999 |
| | 328.00 | 138.634 | 128.559 |
| | 329.00 | 173.769 | 161.859 |
| | 330.00 | 210.029 | 198.870 |
| | 331.00 | 248.889 | 239.561 |
| **FRL** | **332.20** | 302.310 | 293.201 |

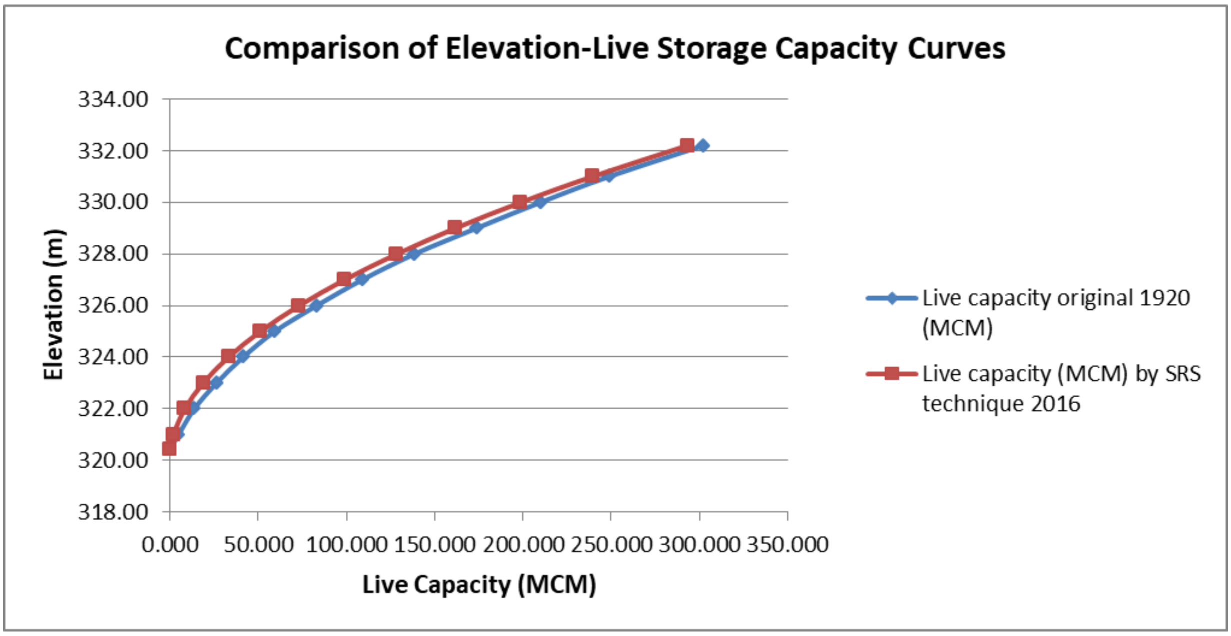



**Fig 13: Comparison of Elevation - Live Storage Capacity curves (MCM)**

## 10 RESULT AND DISCUSSIONS

The loss in live storage capacity of the reservoir due to sedimentation since original survey has been shown in Table 5.

**Table-5: Live storage capacity loss due to sedimentation**

| Details | Original (1920) | SRS (2016) CWC |
|---|---|---|
| Live Capacity in MCM | 302.31 | 293.20 |
| Loss in live capacity in MCM | - | 9.11 |
| % Live capacity loss (since 1920) | - | 3.01 |
| Annual % live capacity loss | - | 0.031 |

## 11 CONCLUSION

The following conclusions emerge from the present study, however subject to the limitations stated in following paragraphs.

- The live storage capacity of Tandula reservoir has been found to be 293.20 MCM in 2016 against the original live storage capacity of 302.31 MCM in 1920.

There is a live capacity loss of 9.11 MCM in 96years which is 3.01% of original live capacity. Annual live capacity loss is 0.031%.

## 12 LIMITATIONS

- As the reservoir operates in between DSL and FRL, the satellite data is available for this range only. The satellite remote sensing based reservoir capacity estimation works between DSL and FRL in live storage.
- Remote sensing techniques give accurate estimate for fan shaped reservoir where there is considerable change in water-spread area with change in water level.
- Data from two to three water years was combined to get the required data set.
- General error can creep in the identification of tail end of reservoir, particularly in the rainy season.

**SALIENT FEATURES** **Annexure-I**

| | | |
|---|---|---|
| 1. | **Name of Reservoir** | Tandula Reservoir |
| 2. | **Location**:<br>a. District<br>b. State<br>c. Longitude<br>d. Latitude<br>e. Year of completion | <br>Balod<br>Chhattisgarh<br>81° 18' 00"<br>20° 42' 00"<br>1920 |
| 3. | **Average Annual Rainfall** | 1282 mm |
| 4. | **River** (on which located) | Confluence of Tandula and Sukha Nala rivers |
| 7. | **Total catchment area** up to dam site | 818 Sq Km |
| 8. | **Salient Levels**:<br>i. Top Bank Level<br>ii. Maximum Water Level<br>iii. FRL<br>iv. MDDL | <br>335.30 m<br>333.40 m<br>332.20 m<br>320.45 m |
| 9. | **Designed storage capacity**<br>i. Gross Storage<br>ii. Live Storage<br>iii. Dead Storage | <br>312.18 MCM<br>302.31 MCM<br>9.87 MCM |
| 10 | **Total Water spread area at FRL** | 4392 Ha. |
| 11 | **(a) Dam Details** | |
| | (i) Length of dam at top | 3819.60 m |
| | (ii) Max. Height | 25.02 m |
| | (iii) Top Width at the Dam | 3.65 m |

**PHOTOGRAPH OF RESERVOIR** **Annexure-II**

**Photo 1: Tandula Reservoir [7]**

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