उपग्रह दूरस्थ संवेदन द्वारा
माताटीला जलाशय, उत्तर प्रदेश का अवसादन आंकलन

SEDIMENTATION ASSESSMENT OF MATATILA RESERVOIR, UTTAR PRADESH, THROUGH SATELLITE REMOTE SENSING

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

May 2019

SEDIMENTATION ASSESSMENT OF

MATATILA RESERVOIR,

UTTAR PRADESH, THROUGH SATELLITE REMOTE SENSING

Year of Survey 2019
Data Used 2017-2018

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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 2017-18 in the sedimentation study of Matatila 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 of Matatila reservoir were 985.71 MCM & 876.69 MCM respectively. According to Satellite Remote Sensing study conducted in 1999 the gross storage capacity of reservoir was reported as 702.33 MCM. After analysis of the satellite data in the present study, it is found that live capacity of the Matatila reservoir in 2018 is 675.065 MCM witnessing a loss of 310.65 MCM (i.e. 31.52 %) in a period of 56 years during 1962 to 2018. This accounts for live capacity loss of 0.56% per annum since 1962.

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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 MATATILA RESERVOIR, UTTAR PRADESH THROUGH SATELLITE REMOTE SENSING

1 INTRODUCTION

India – the second largest country in the world in terms of population – has about 17.3% of world's population, about 4% of world's water resources, and 2.44% of total geographical land area of the world. Therefore, in spite of having an average annual average precipitation to the tune of more than 1127.1 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%) in rivers is available only in these three months. 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 in 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 Matatila reservoir, Uttar Pradesh 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).

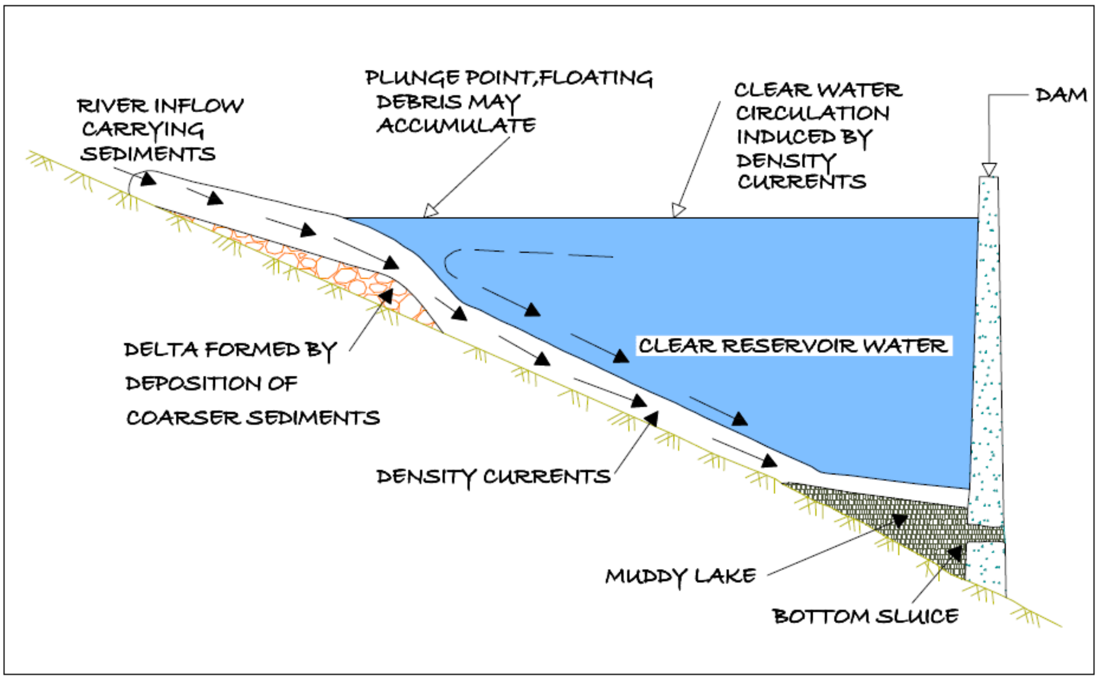


Fig. 1: Conceptual sketch of density currents in a reservoir

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.

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.

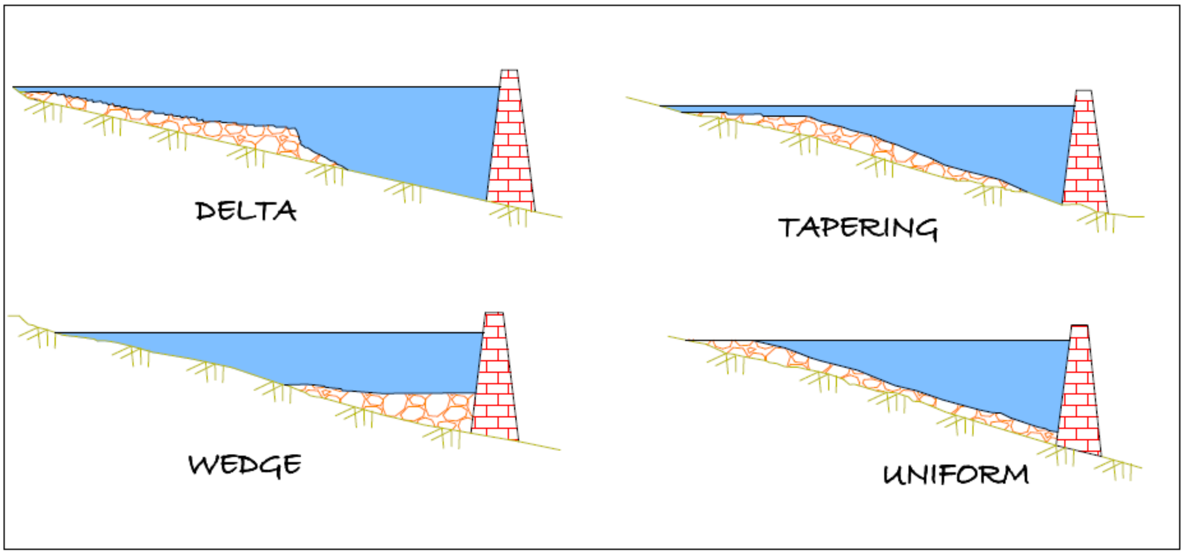


Fig. 2: Longitudinal Patterns of sediment deposition in reservoirs.

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.

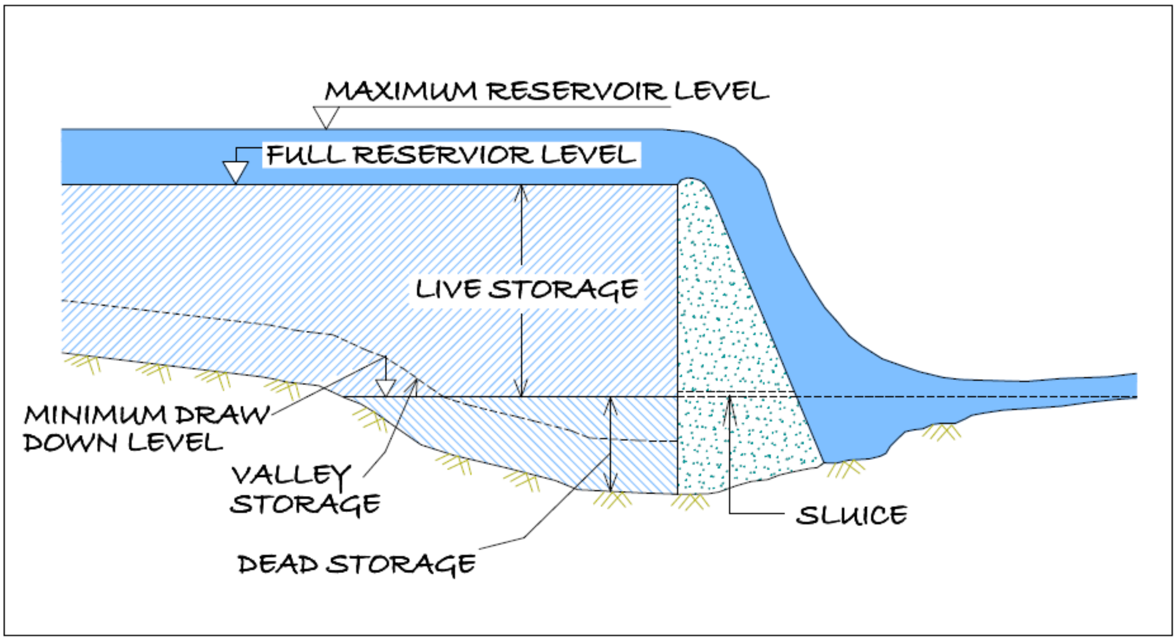


Fig. 3: Conceptual sketch of different levels in a reservoir

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.

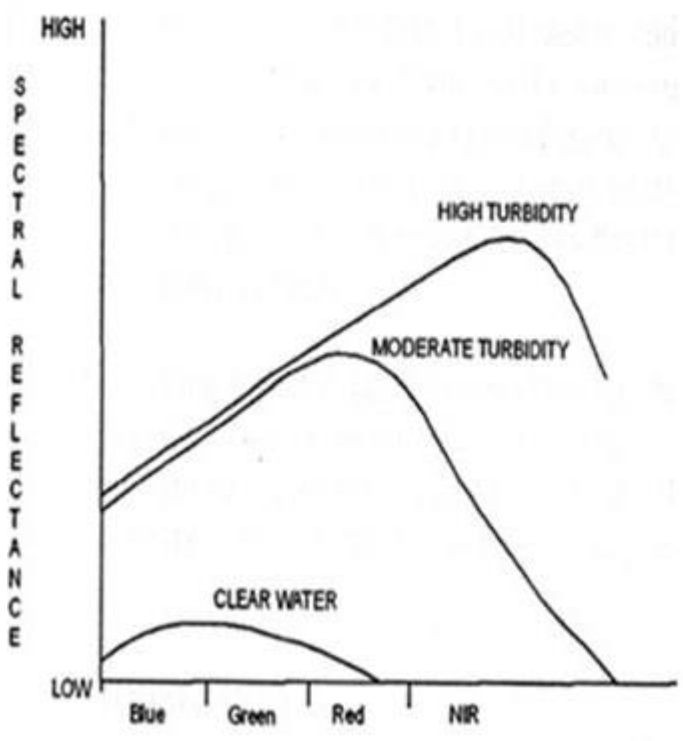


Fig. 4: Reflectance curves for Clear and Turbid water

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 Matatila 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
c) Comparison of results with previous hydrographic/SRS surveys.

6. STUDY AREA

Matatila Dam was constructed in the year 1956 across river Betwa which is a tributary of river Yamuna. The dam lies at 25°6’15” North Latitude and 78°23’00” East Longitude. It is located at Matatila in District and Tehsil Lalitpur of U.P., which is 56 km. from Jhansi. It is situated 4.8 km. southwest of Basai railway station on the left bank of Betwa River, and 11.25 km. northwest of Talbehat railway station on the Right Bank. The catchment area of the dam is 20,720 km^2. Fig-5 is the index map showing the location of the Matatila reservoir.

It is an earth dam 6.6 km. long with masonry spillway of ogee shape. The maximum heights of the earthen dam above ground, maximum height of spillway and maximum height of non-spillway section are 24.40m, 33.55m and 36.36m respectively. It has 23 vertical lifting gates and 4 sluices. It has designed dead storage of 113.30 Million Cubic meters below RL 295.66m and a live storage of 1019.40 Million Cubic meters between RL 295.66m and FRL of 308.46m. The total capacity of the reservoir is thus 1132.70 Million Cubic meters at FRL 308.46m with water spread area of 142.43 sq.km. It provides facilities for irrigation, power generation, water supply and fish cultivation. The dam was completed in 1956 with the spillway upto the crest level at RL 301.45m. The spillway gates were erected later and the reservoir could be filled up to the FRL for the first time in 1964.

Salient features of the project are given at Annex-I.

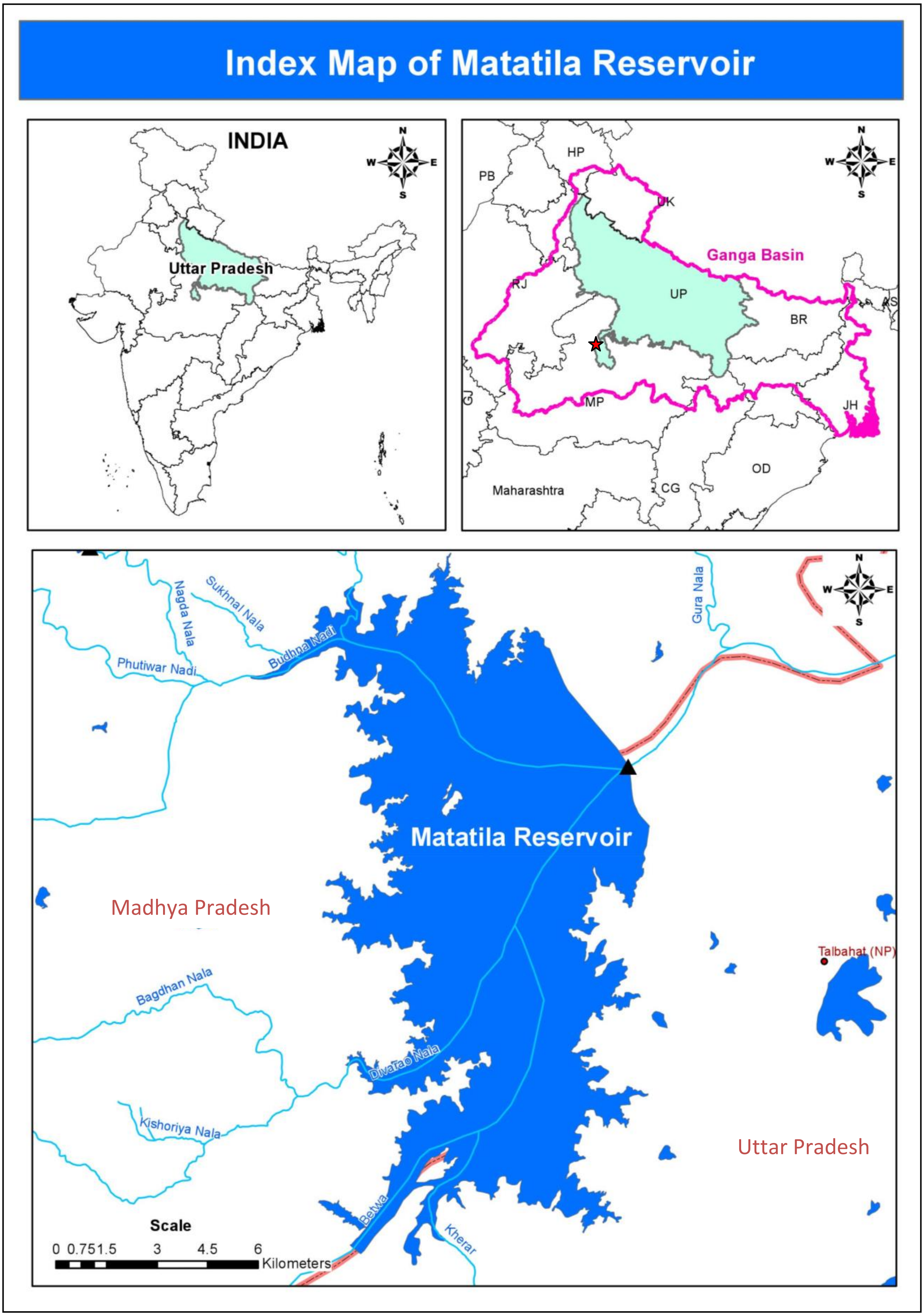


Fig. 5: Index map of the Matatila Reservoir

7. HYDROGRAPHIC SURVEYS

A number of Hydrographic surveys in Matatila reservoir have been conducted so far by U.P. Irrigation Research Institute, Roorkee in pre-monsoon period of the year 1962, 1964, 1966, 1969, 1971, 1975, 1985,1990, 1994.

The first capacity survey of Matatila reservoir was conducted before the monsoon of 1962, when the reservoir was practically empty. The gross capacity and dead storage capacity were worked out to 985.71 MCM and 109.02 MCM whereas its original gross and dead storage capacity as per project report are 1132.70 MCM and 113.30 MCM respectively. Because the capacity for the project purpose was estimated earlier in 1956 on the basis of inadequate survey, the gross capacity of 985.71 MCM has been taken as the basis for the purpose of determining the loss in capacity in subsequent years (page-10 of Completion Report on "Estimation of Sediment Deposits in Matatila Reservoir of Uttar Pradesh" October-1985). The stream bed elevation, as per 1962 survey was 280.40m. The same has been used in the present study also for determining losses etc.

The gross and dead storage capacity in 1975 reduced to 882.87 MCM and 52.06 MCM. The 1975 hydrographic survey indicated a total capacity loss of 10.43% of its 1962 pre-monsoon capacity, indicating an average reduction of 0.8% per year. Average silting rate was worked out as 381.8 m^3/sq.km./year against the assumed value in the design being 132 m^3/sq.km./year. The new zero elevation was worked out as 286.16m. It was also estimated that the reservoir would be filled upto dead storage level by the year 1996.

As per the hydrographic survey in pre-monsoon period of the year 1985, the gross capacity and dead storage capacity were worked out to 784.30 MCM and 35.71 MCM respectively. The new zero elevation was worked out as 286.60m. The total loss in capacity was 20.43% in 23 years of its 1962 pre-monsoon capacity, which indicated an average reduction of 0.89% per year. The average silting rate was worked out as 422.63 m^3/sq.km./year.

The gross and dead storage capacity in 1990 reduced to 748.72 MCM and 25.49 MCM. The 1990 hydrographic survey indicated a total capacity loss of 24.04% of its 1962 pre-monsoon capacity, indicating an average reduction of 0.86% per year. Average silting rate was worked out as 408.50 m^3/sq.km./year.

In 1999 a Satellite Remote Sensing Survey was conducted which indicated a total capacity loss of 28.75% of its 1962 pre-monsoon capacity. The gross storage capacity was reported as 702.33MCM and average silting rate was worked out as 369.64 m^3/sq.km./year.

8. 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 Matatila reservoir, the height difference between FRL (308.46 m) and MDDL (295.66 m) is 12.80 m.

9. DATA USED

9.1. SATELLITE DATA

Landsat 8 OLI/TIRS C1 data for seven (07) 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	Date of pass	Elevation (m)
Landsat 8 OLI/TIRS C1	11-OCT-2018	308.460
Landsat 8 OLI/TIRS C1	24-OCT-2017	307.030
Landsat 8 OLI/TIRS C1	09-NOV-2017	306.350
Landsat 8 OLI/TIRS C1	25-JAN-2017	305.530
Landsat 8 OLI/TIRS C1	30-MAR-2017	304.710
Landsat 8 OLI/TIRS C1	01-MAY-2017	303.790
Landsat 8 OLI/TIRS C1	17-MAY-2017	301.290

9.2. FIELD DATA

The following field data has been obtained from project authorities:

Elevation - Capacity data

Salient features of Matatila reservoir levels and capacity data on specified dates

10. 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 Matatila reservoir studies, multi-date Landsat 8 OLI/TIRS C1 (07 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.

10.1. DATA BASE

The satellite data corresponding to reservoir area obtained from USGS Earth Explorer was loaded on the system. Bands 6,5,4 of the geo-referenced images for all seven different dates pertaining to study area were used for further analysis.

10.2. 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

10.2.1. 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.

10.2.2. 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. 7 shows FCC's of different dates and Fig. 8 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 (30m x 30m).

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 project authtorites.

Table – 2: Water Spread Areas estimated from Satellite Images

Date of pass	Elevation (m)	Area (M Sqm)
11-OCT-2018	308.460	115.127
24-OCT-2017	307.030	106.133
09-NOV-2017	306.350	96.746
25-JAN-2017	305.530	86.776
30-MAR-2017	304.710	78.172
01-MAY-2017	303.790	63.929
17-MAY-2017	301.290	44.850

10.2.3. NDVI ANALYSIS STEP BY STEP:

1. Add images in Band 1 to 7 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. 6).

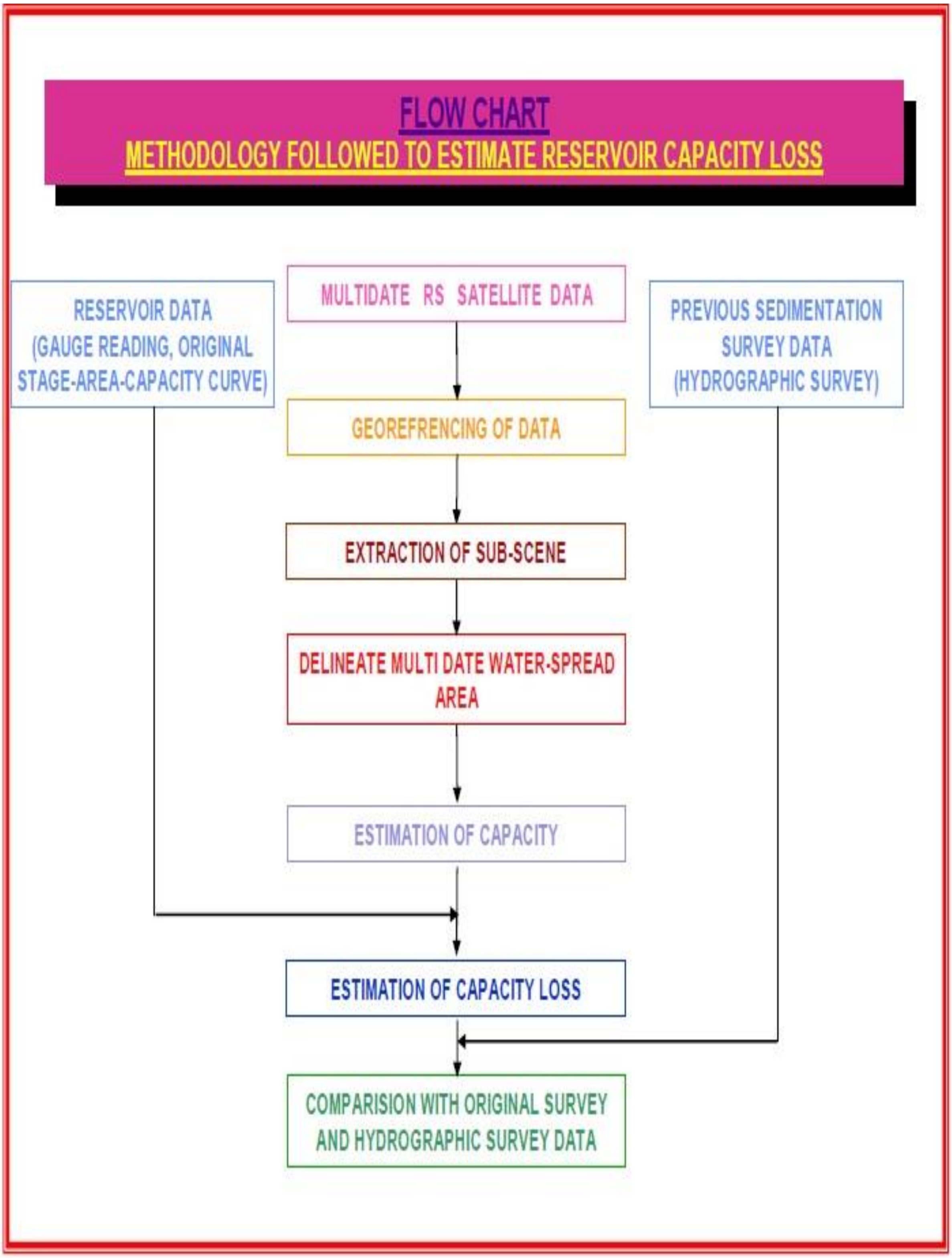
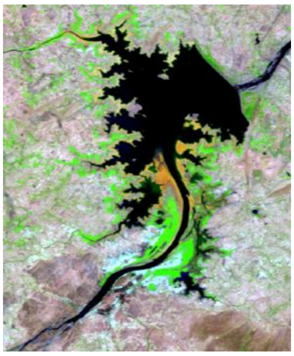
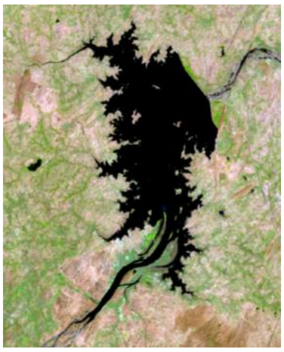


Fig 6 : Flow chart showing methodology followed to estimate reservoir capacity loss



17-May-2017(301.29m)

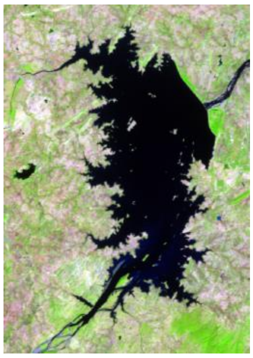
01-May-2017(303.79m)



30-Mar-2017(304.71m)

25-Jan-2017(305.53m)

09-Nov-2017(306.35m)



24-Oct-2017(307.03m)

11-Oct-2018(308.46m)

Fig 7 : False Colour Composites(FCCs) showing water spreads at different dates

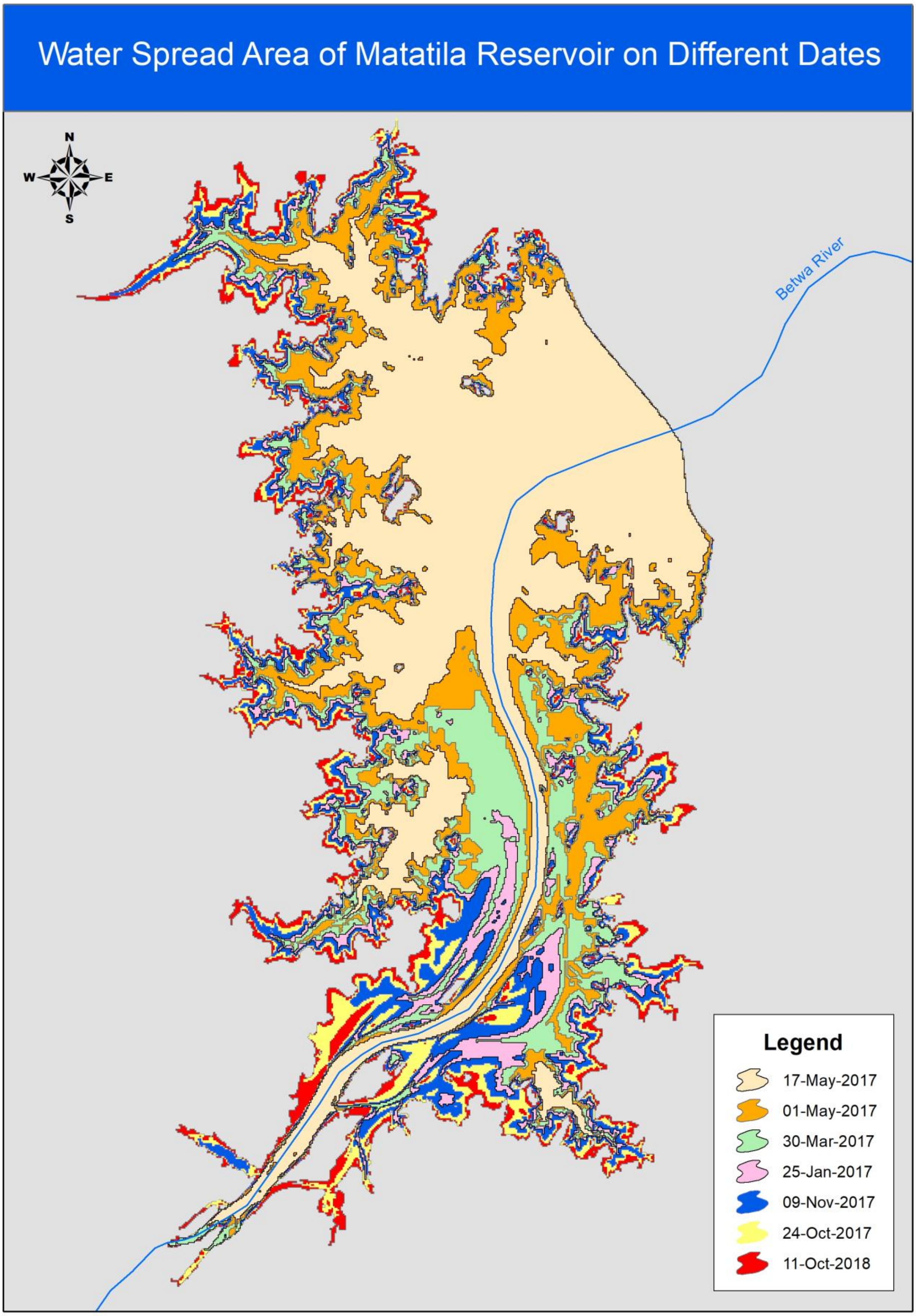


Fig. 8: Matatila Reservoir Water Spread Area on different dates

The Satellite Images for the Matatila reservoir have been obtained from USGS Earth Explorer. The analysis has been carried out using Digital Image Processing software Arc GIS. The digitally processed images of Matatila Reservoir showing its water spread area for seven overpass dates such as 11-Oct-2018, 24-Oct-2017, 09-Nov-2017, 25-Jan-2017, 30-Mar-2017, 01-May-2017, and 17-May-2017 are shown in fig. 8.

The water elevation 308.46 for 11th Oct, 2018 is at the Full Reservoir Level (FRL) of 308.46m and water elevation 301.290m for 17th May, 2017 is above the Minimum Drawdown Level (MDDL) of 296.0 m.

10.3. ESTIMATION OF RESERVOIR CAPACITY

Area elevation curve has been plotted using these above seven (07) 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 = 0.0708*X^2 +9.1434 * X -7.0469

R^2 = 0.9869

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-9. 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-10 and Fig-11 respectively.

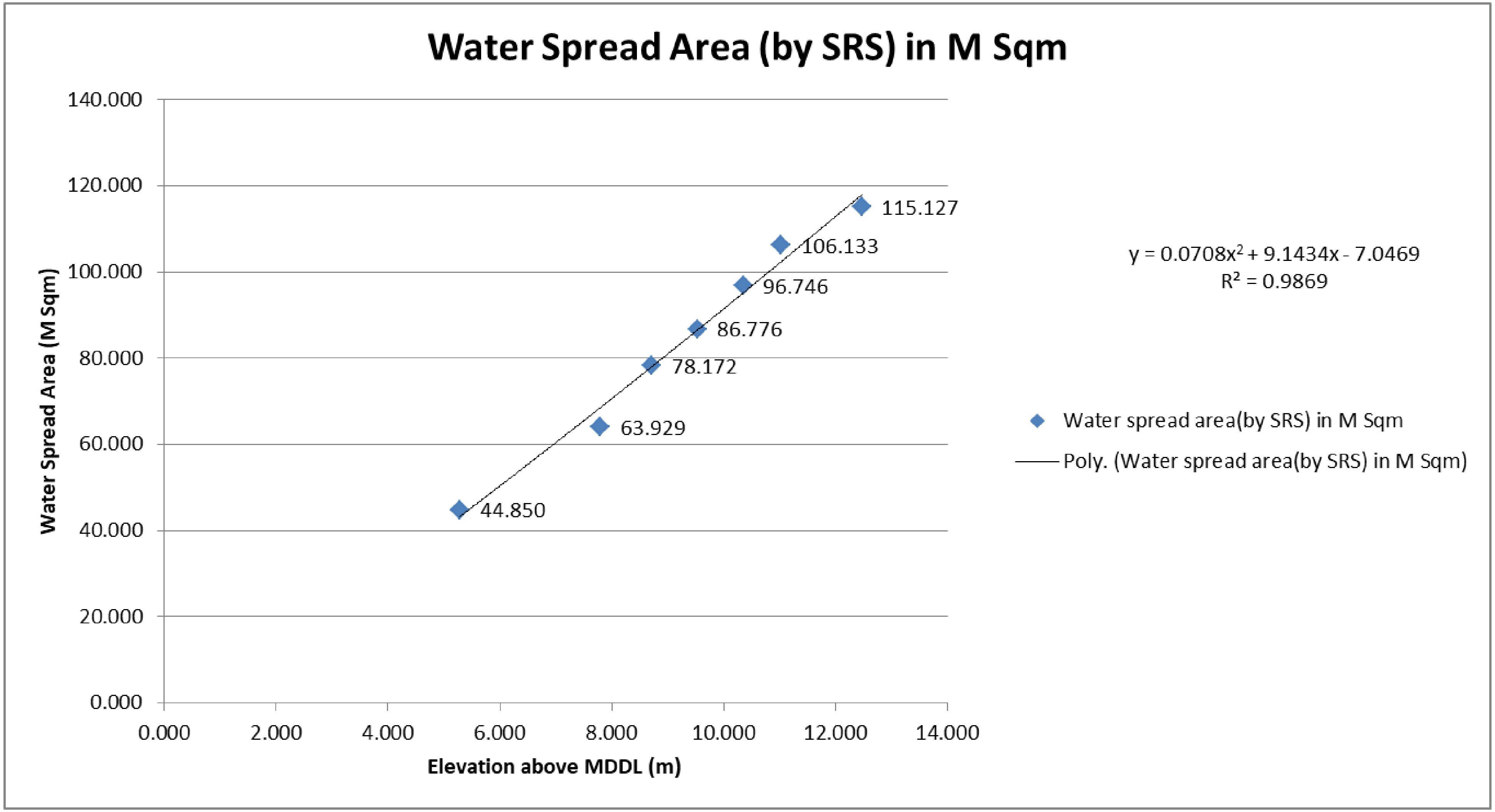


Fig. 9: Water spread Area of Matatila Reservoir

Table-3: Aerial extent of reservoir at regular interval (1.0m) using SRS Survey 2018

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	**295.66**	*		
	296.766	0	0	0
	297.00	2.167	6.430	6.430
	298.00	11.523	6.229	12.659
	299.00	21.021	16.036	28.695
	300.00	30.660	25.689	54.384
	301.00	40.440	35.437	89.821
	302.00	50.362	45.311	135.132
	303.00	60.426	55.318	190.449
	304.00	70.632	65.462	255.912
	305.00	80.979	75.746	331.658
	306.00	91.467	86.170	417.828
	307.00	102.097	96.734	514.561
	308.00	112.869	107.438	621.999
FRL	**308.46**	117.872	53.066	675.065

*The nearest satellite image to MDDL (295.66 m) was available at an elevation of 301.290 m. In the last 1 decade the reservoir level was never recorded below 300m the lowest level reached being 300.810m on 29th June 2009. The water spread area at MDDL was found to be negligible when extrapolated from the area-capacity curve of the reservoir indicating that dead storage capacity of the reservoir has been almost exhausted.

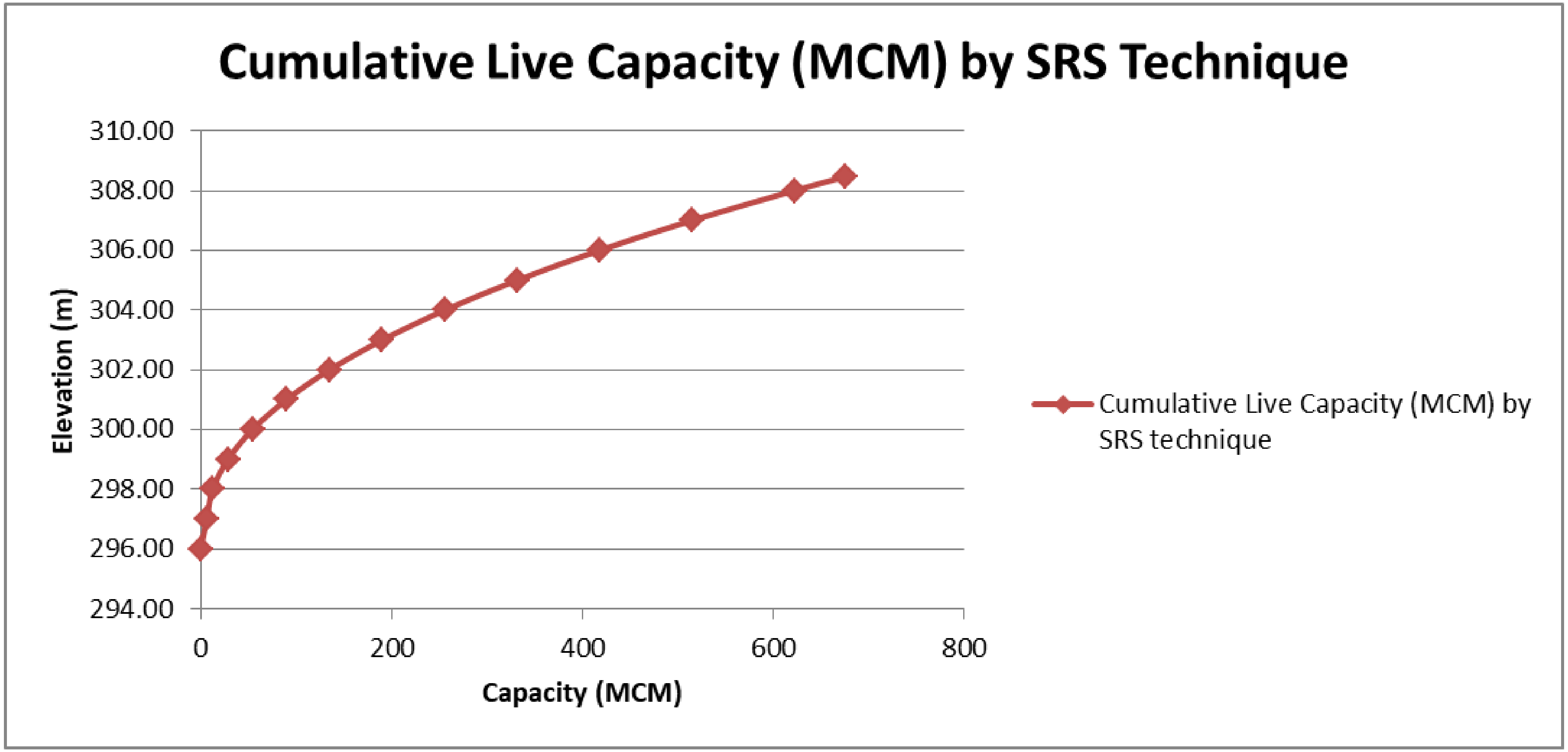


Fig. 10: Modified live capacity - elevation curve (SRS technique)

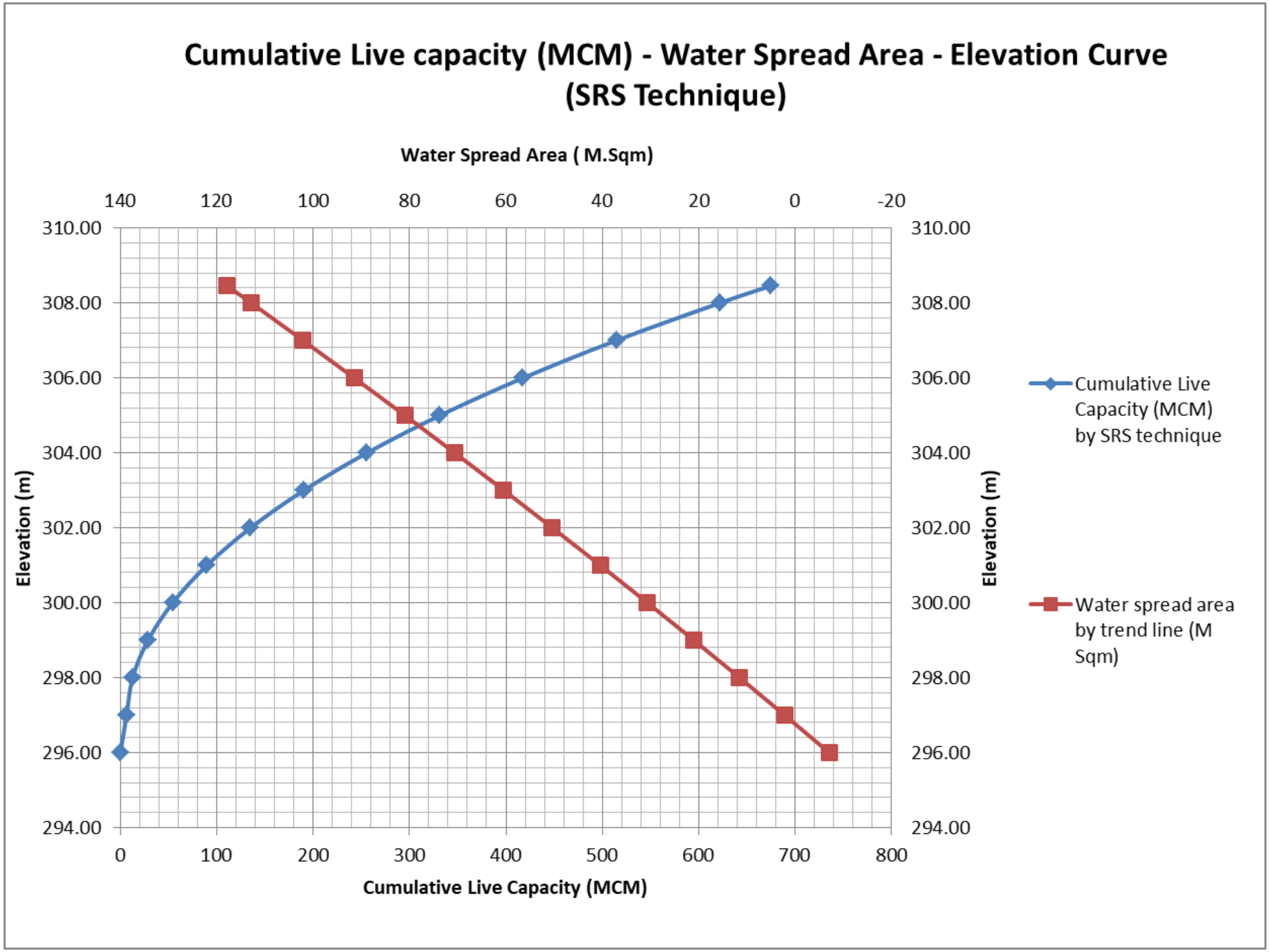


Fig. 11: Elevation – Area- Capacity Curve

10.4. COMPARISON WITH PREVIOUS SURVEYS

Table-4 shows the comparison of present storage capacity with original capacity as well as capacity of hydrographic and SRS survey at various elevations.

Table - 4: Comparison of Gross Storage Capacity of Reservoir

Elevation(m)	Original (MCM)	Capacity / Hydrographic Surveys (MCM)				SRS (MCM)	SRS (MCM)
	1956	**1962**	**1975**	**1985**	**1990**	**1998-99**	**2017-18**
MDDL 295.66	113.30	109.02	52.06	35.71	25.49	0.00	0.00
296.0		117.94	57.32	40.24	29.36	0.00	0.00
296.15		121.69	61.20	43.26	31.99	0.00	0.00
298		177.52	109.10	80.49	64.43	13.99	12.659
300		268.66	186.46	147.38	125.85	65.26	54.384
302		386.05	292.07	236.24	217.62	153.69	135.132
304		539.21	432.56	356.55	338.66	280.00	255.912
306		717.87	608.30	525.28	499.60	444.99	417.828
FRL 308.46	1132.70	985.71	882.87	784.30	748.72	702.33	675.065

Curves showing comparison between original capacity, present capacity and the capacity of hydrographic survey at various levels of reservoir are drawn in Fig-12. The graph has been plotted for elevations above MDDL.

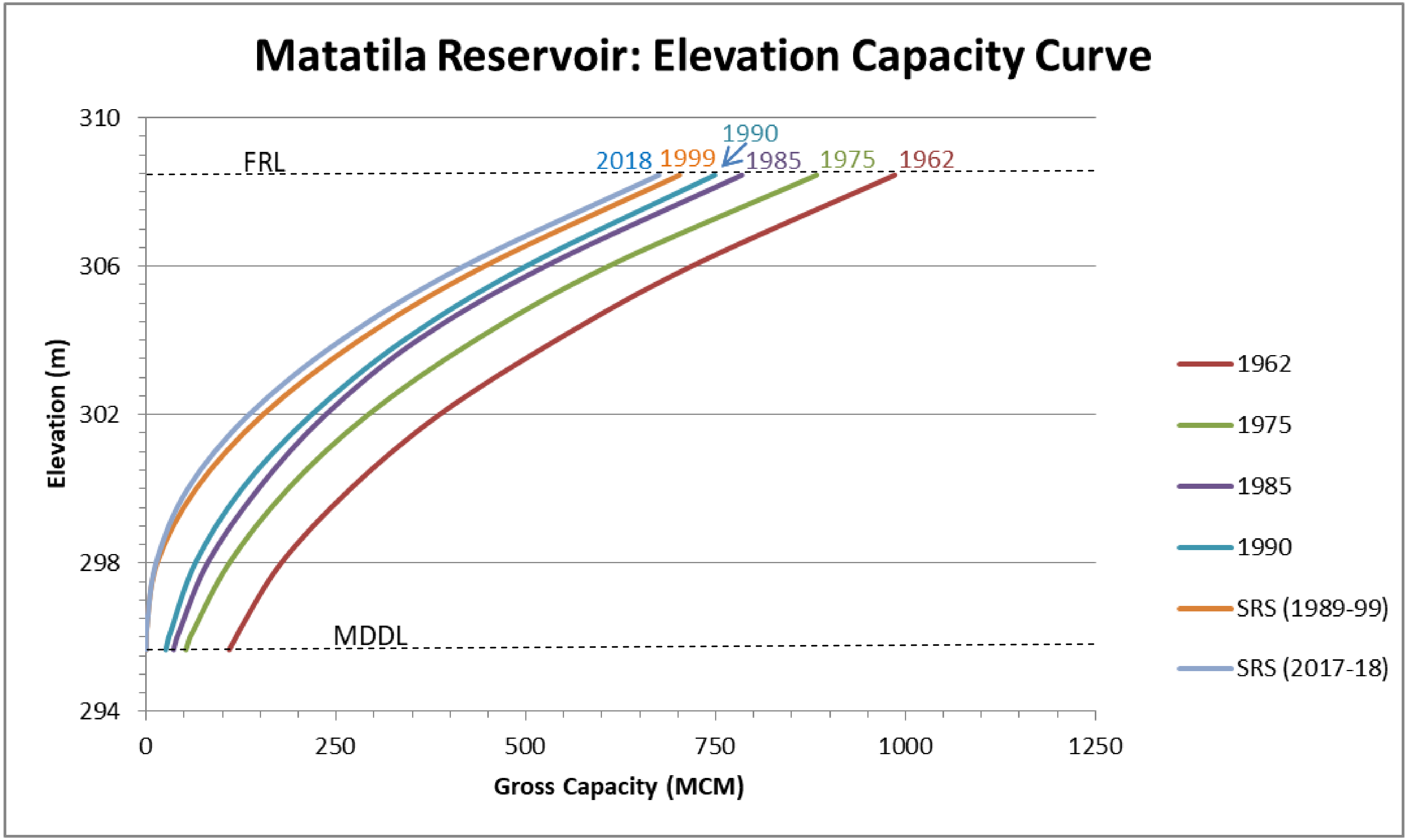


Fig. 12: Comparison of Elevation - Capacity Curves in different surveys of the reservoir

11. RESULTS AND DISCUSSIONS

Storage capacity loss due to sedimentation (1962-2018) carried out by present study and as per previous hydrographic and SRS surveys is given in Table –5.

Table – 5 : Storage Capacity loss due to sedimentation as per original survey (1962)

	1962	1975	1985	1990	1998-1999 (SRS)	2017-2018 (SRS)
Gross Capacity (MCM)	985.71	882.87	784.30	748.72	702.33	675.065
Loss in Capacity (MCM)		102.84	201.41	236.99	283.38	310.645
% loss		10.43	20.43	24.04	28.75	31.52
Annual % loss		0.80	0.89	0.86	0.78	0.56

The gross storage capacity of Matatila reservoir as per present study is found to be 675.065 MCM for the year 2017-18. As per the last SRS survey conducted in 1999 the gross storage capacity is 702.33 MCM. Modified elevation-area-capacity table worked out by the present study is given at Table 3.

11.1. Rate of Siltation

Rate of sediment deposition carried out by present study and as per previous hydrographic and SRS surveys is given in Table –6.

Table – 6: Rate of siltation in the reservoir

S. No.	Year of Survey	Period (Years)	Reservoir Gross Storage Capacity (MCM)	Loss of Capacity (MCM)	Observed Rate of Siltation Since Last Survey
				Since Last Survey	(m^3/sq.km./year)
1.	1962		985.71		
2.	1975	13	882.87	102.84	381.794
3.	1985	10	784.3	98.57	475.724
4.	1990	5	748.72	35.58	343.436
5.	1999	9	702.33	46.39	248.767
6.	2018	19	675.065	27.265	69.257*

*The average rate of siltation in previous surveys was much higher than the assumed rate of siltation of 132.0 m^3/sq.km./year at the time of planning. In the present study, the rate of siltation since last survey of 1999 is 69.257 m^3/sq.km./year. The reduction in siltation rate may be attributed to construction of Rajghat dam in 2006, about 50 Km upstream of the Matatila dam. Due to the construction of Rajghat dam, the silt load would have been drastically reduced during the past 13 years, thereby lowering the average rate of siltation calculated for the period since last survey i.e. 1999-2018.

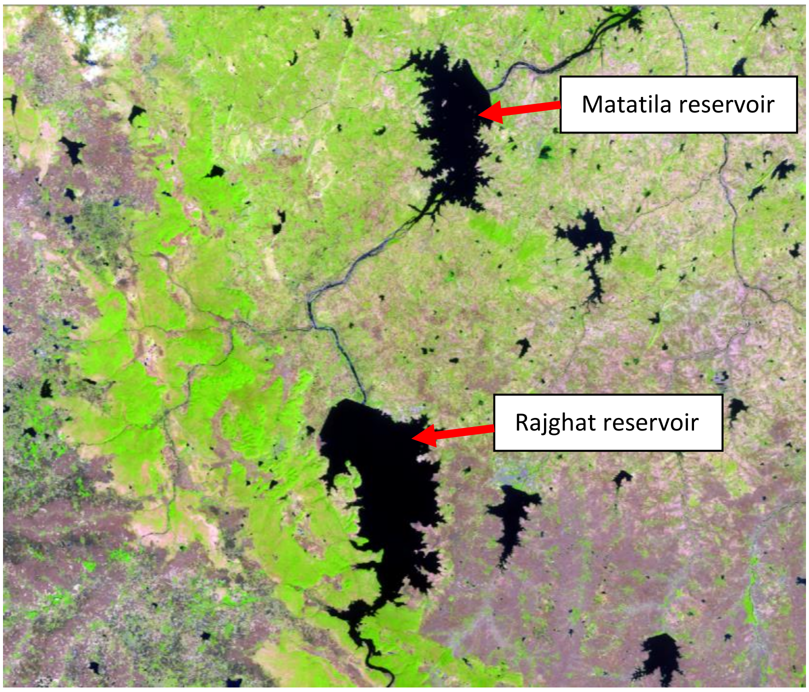


Fig. 13: False Colour Composite(FCC) showing water spread in Rajghat and Matatila dam on 11-Oct-2018

13. CONCLUSION

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

1. The gross storage capacity of Matatila reservoir has been found to be 675.065 MCM in 2018.
2. Capacity loss of 31.52% was observed in gross storage, in a period of 56 years (annual loss 0.56 %) since first capacity survey of 1962.
3. An average rate of siltation since last survey in 1999 is 69.257 m^3/sq.km./year. In comparison to previous surveys, the siltation rate has reduced drastically owing to the construction of Rajghat dam in the upstream of Matatila Dam.
4. Satellite remote sensing based survey gives the information on the capacities in the water level fluctuation zone only, which generally lies between MDDL and FRL of the reservoir. Use of Satellite Remote Sensing technique enables a fast and economical estimation of live storage capacity loss due to sedimentation.
5. Capacity estimation by this technique at regular time interval can give important parameters like annual rate of sedimentation and sediment deposition pattern in the reservoir area and provide new elevation - area - capacity curve for optimal operation of the reservoir.

13. LIMITATIONS/OBSERVATIONS

1. As the reservoir operates between MDDL and FRL, the satellite data is available for this range only. The satellite remote sensing based reservoir capacity estimation works between MDDL and FRL in live storage.
2. Remote sensing techniques give accurate estimate for fan shaped reservoir where there is considerable change in water-spread area with change in water level.
3. Data from more than one hydrological year (2 calendar years) was combined to get the required data set.
4. General error can creep in the identification of tail end of reservoir, particularly in the rainy season.
5. Ground truth verification of boundary pixels is not possible due to continuous variation in reservoir levels which prevents correlating field observation of reservoir boundary with satellite data.

Annexure-I

SALIENT FEATURES OF MATATILA DAM RESERVOIR

1.	Total Length of Dam	6,320.00 m.
2.	Maximum height of non-spillway	36.56 m.
3.	Maximum height of spillway	33.55 m.
4.	Maximum height of earthen dam above ground	24.40 m.
5.	Fell reservoir let level	308.46 m.
6.	Highest reservoir let level	310.04 m.
7.	Top of crest	301.45 m.
8.	Top of non-spillway	310.90 m.
9.	Capacity at FRL (Designed)	1,132.7 MCM
10.	Catchment area of River Betwa at Matatila Dam site	20,720 sq.km.
11.	Maximum expected flood	23,350cumecs
12.	Flood escaping capacity	15,850cumecs
13.	Number of gates over spillway	23
14.	Size of gates	18.3 X 7.0 m
15.	Clear length of spillway	420.00 m.
16.	Length of spillway excluding piers	490.0 m.
17.	Length of non-spillway (abutments, undersluices and power House)	247.2 m.
18.	Total area submerged at FRL	143.43 sq.km.
19.	Proposed irrigation in UP	1,04,611 ha.
20.	Proposed irrigation in MP	62,322 ha.
21.	Proposed installed capacity of power house	30 MW
22.	Owner	Irrigation Department
23.	River	Betwa

24.	State	UP
25.	Latitude	25^{o}06’15”
26.	Longitude	78^{o} 23’00”
27.	Nearest district	Lalitpur
28.	Stream bed elevation	276 m.
29.	Top of dam elevation	310.90 m.
30.	Spillway crest elevation	301.45 m.
31.	Top of gate elevation	308.46 m.
32.	Date of storage began	June 1956
33.	Date of normal operation began	05-July-1964
34.	Lowest outlet elevation.	280.42 m.
35.	Length of reservoir	20.1 km.
36.	Average width of reservoir	7.0 km.
37.	Net sediment contributing area	20577 sq.km.
38.	Annual runoff	6,000 MCM

Annexure-II

PHOTOGRAPH OF RESERVOIR

Photo 1: Matatila Reservoir

Photo 2: Matatila Reservoir

References

1. Muley M V. Application of Remote Sensing in the study of reservoir Sedimentation, SAC, Ahemedabad, June 2001.
2. Linsley R K and Franzini J B Reservoirs. Water resources Engineering, II ed. Mc Graw Hill Kogakusha ltd, 1972,pp.161-185
3. Borland W M and Miller C R (1960), Distribution of sediment in large reservoirs. Transactions of American Society of civil engineers, vol.125, 1960
4. Compendium on silting of reservoirs in India (2015), WS&RS directorate, Environment Management Organization, WP&P wing, CWC, pp1-194.
5. Sedimentation Analysis of Matatila Reservoir through Satellite Remote Sensing (2001), Remote Sensing Directorate, Environment Management Organization, WP&P wing, CWC, pp1-23.

Publication Reg. No. : CWC/2021/82