सत्यमेव जयते

उपग्रह दूरस्थ संवेदन द्वारा
स्टेनली जलाशय का अवसादन आकलन

SEDIMENTATION ASSESSMENT OF STANLEY RESERVOIR (METTUR DAM), TAMIL NADU THROUGH SATELLITE REMOTE SENSING

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

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SEDIMENTATION ASSESSMENT OF STANLEY RESERVOIR, TAMIL NADU, THROUGH SATELLITE REMOTE SENSING

Year of Study **2020**
Data Used **2018-2019**

STUDY TEAM

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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 **Microwave Remote Sensed data** for the years 2018-19 in the sedimentation study of Stanley 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.

In the present study **microwave data from Sentinel 1A satellites** have been used to estimate water spread area of Stanley Reservoir. As compared to Optical remote sensing, Microwave remote sensing has advantages as the satellite operates day and night allowing the acquisition of imagery at frequent time intervals regardless of weather and illumination conditions. The Sentinel-1 mission is a constellation of two polar-orbiting satellites (Sentinel-1A and Sentinel-1B), with a C-band synthetic aperture radar instrument operating at a center frequency of 5.405 GHz, that acquires Synthetic Aperture Radar (SAR) data in single or dual polarization with a revisit time of 6 days.

The original gross and live storage capacities of Stanley reservoir at the time of opening in 1934 were 2708.76 MCM & 2646.74 MCM respectively. Hydrographic surveys were conducted for this reservoir in 1978, 1984. After analysis of the satellite data in the present study, it is found that live capacity of the Stanley reservoir in 2019 is 2150.55 MCM witnessing a live storage loss of 496.19 MCM (18.75%) in 85 years i.e. 0.22% every year. Also, **this is the first time that SRS based study is ever conducted on this reservoir using Microwave imageries as cloud-free optimal imageries at different levels were not available for this reservoir in previous years.**

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

CWC	Central Water Commission
DSL	Dead Storage Level
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
SAR	Synthetic Aperture Radar
SNAP	Sentinel Application Platform
SRS	Satellite Remote Sensing
N.A.	Not Available
WSA	Water Spread Area

UNITS USED

Cumec	cubic metre per second
m	Metre
M m^2	million square metre
M m^3/MCM	million cubic metre
Ha	Hectare
Sq Km	Square Kilometre
mm/year	millimetre per year

SEDIMENTATION ASSESSMENT OF STANLEY RESERVOIR, TAMILNADU 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 1105 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 3880 BCM. Out of this precipitation, the average annual water resources availability of the country is about 1999.2 BCM, as estimated by Central Water Commission (CWC) in 2019. 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 1122 BCM (690 BCM of surface water and 432 BCM of groundwater). On one hand, the per-capita water resource availability is reducing due to increasing population and on the other, per-capita water usage is increasing due to industrialisation, 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 Stanley reservoir (Mettur Dam), Tamil Nadu 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

Reservoirs created by dams on rivers lose their storage capacity due to sedimentation. 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". A large proportion of the transported silt eventually gets deposited at different levels of a reservoir and causes reduction not only in dead storage but also in live storage capacities.

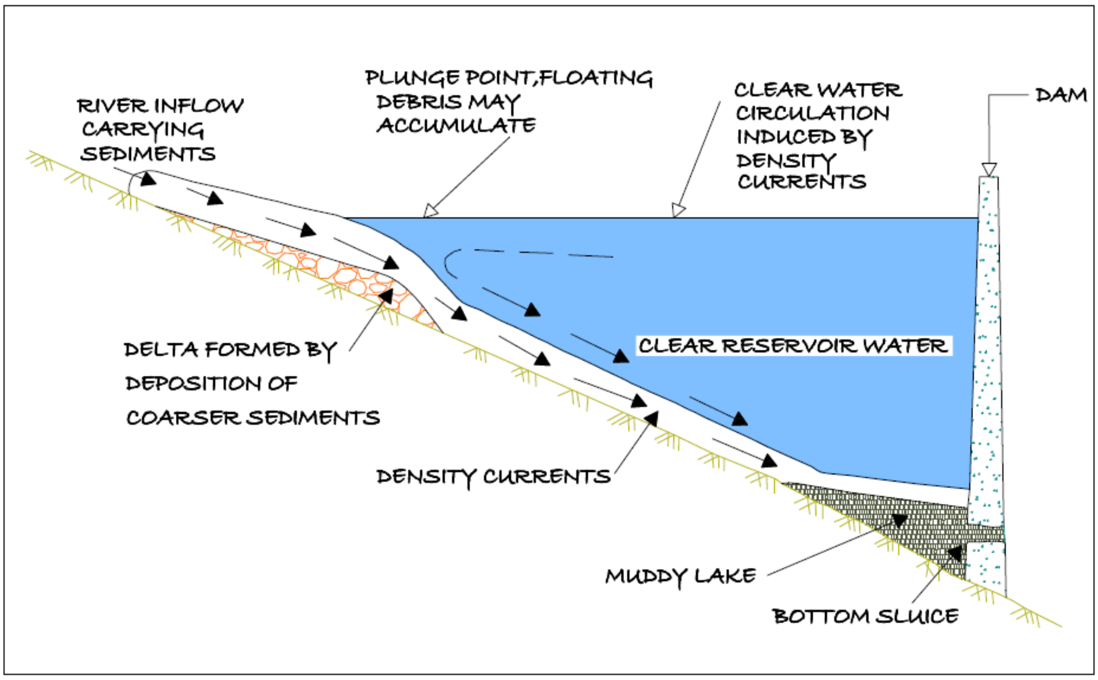


Fig. 1: Conceptual sketch of density currents in a reservoir

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.

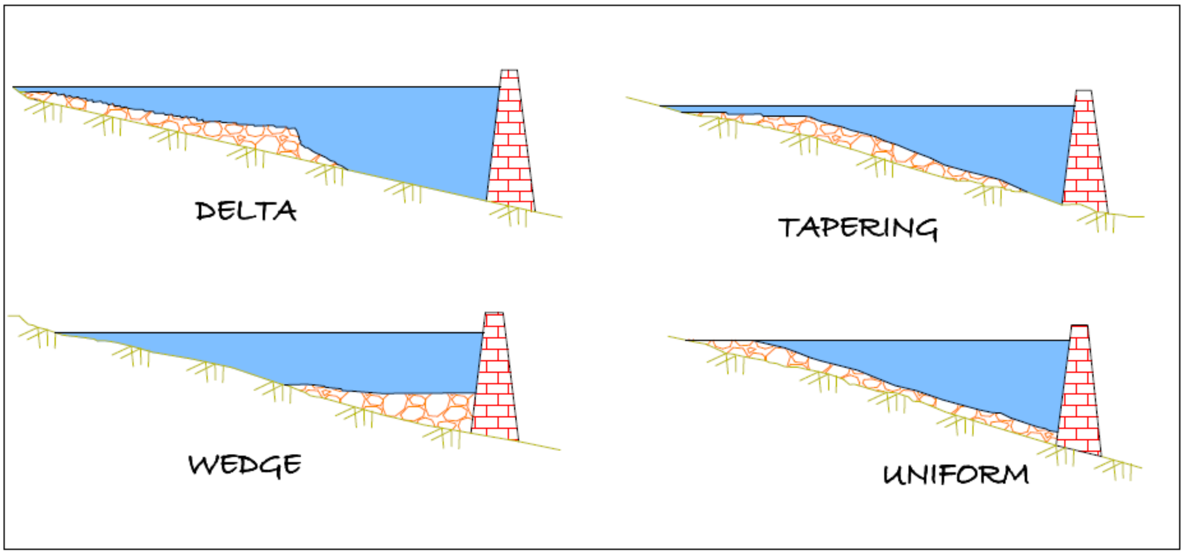


Fig. 2: Longitudinal Patterns of sediment deposition in reservoirs.

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.

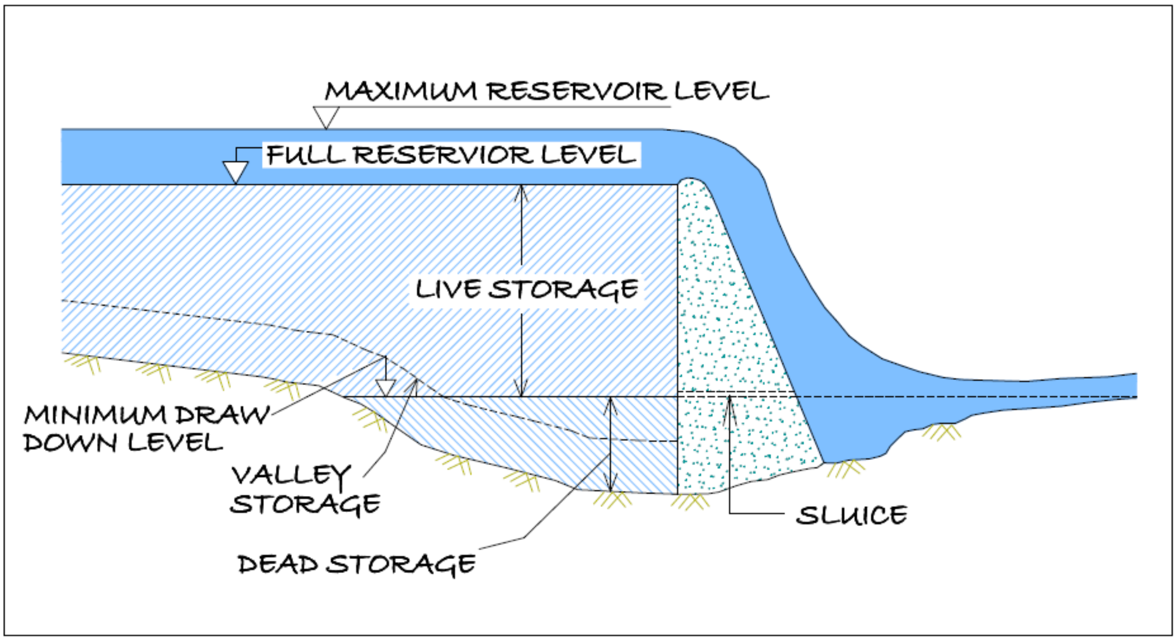


Fig. 3: Conceptual sketch of different levels in a reservoir

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 useful for mapping and monitoring the surface water bodies and other land resources based on which, better water management strategies could be planned. Data from microwave remote sensing technique such as SENTINEL-1 is more useful as it is an imaging radar mission providing continuous all-weather, day-and-night imagery at C-band. The SENTINEL-1 constellation provides high reliability, improved revisit time, geographical coverage and rapid data dissemination to support operational applications in the priority areas of marine monitoring, land monitoring and emergency services.

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.

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 that was a limitation in earlier optical analysis has been taken care of by using microwave datasets that are not affected by weather or illumination conditions. 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 Stanley 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

The Mettur Dam which creates Stanley Reservoir is one of the largest dams in India and the largest in Tamil Nadu, located across the river Cauvery where it enters the plains. Three minor tributaries – Palar, Chennar and Thoppar – enter the Cauveri on her course above Stanley Reservoir. Built in 1934, it took 9 years to complete. The dam receives inflows from its own catchment area, Kabini Dam and Krishna Raja Sagara Dams located in Karnataka. It provides irrigation and drinking water facilities for more than 12 districts of Tamil Nadu and hence is revered as the life and livelihood-giving asset of Tamil Nadu.

The Stanley reservoir in the Salem district of Tamil Nadu State is located at 11° 48′ 00″ North Latitude and 77° 48′ 00″ East Longitude. The reservoir is formed in 1934 by construction of Mettur Dam. The index map showing the location of the Stanley reservoir is given in Fig-4. This is a multipurpose project catering to Hydropower, irrigation & drinking water needs. Salient features of the Mettur project are given in Annexure 1. This is an important reservoir considering fisheries in Tamil Nadu.

The catchment area of the Stanley reservoir is about 42200 sq km. The catchment receives rainfall both during the southwest monsoon and the northeast monsoon.

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. But in this study, water level in Stanley Reservoir went below MDDL for the water year taken for study. In the case of Stanley reservoir, the height difference between FRL (240.79 m) and MDDL (219.456m) is 21.334 m.The Dead Storage level is at 204.216 m.

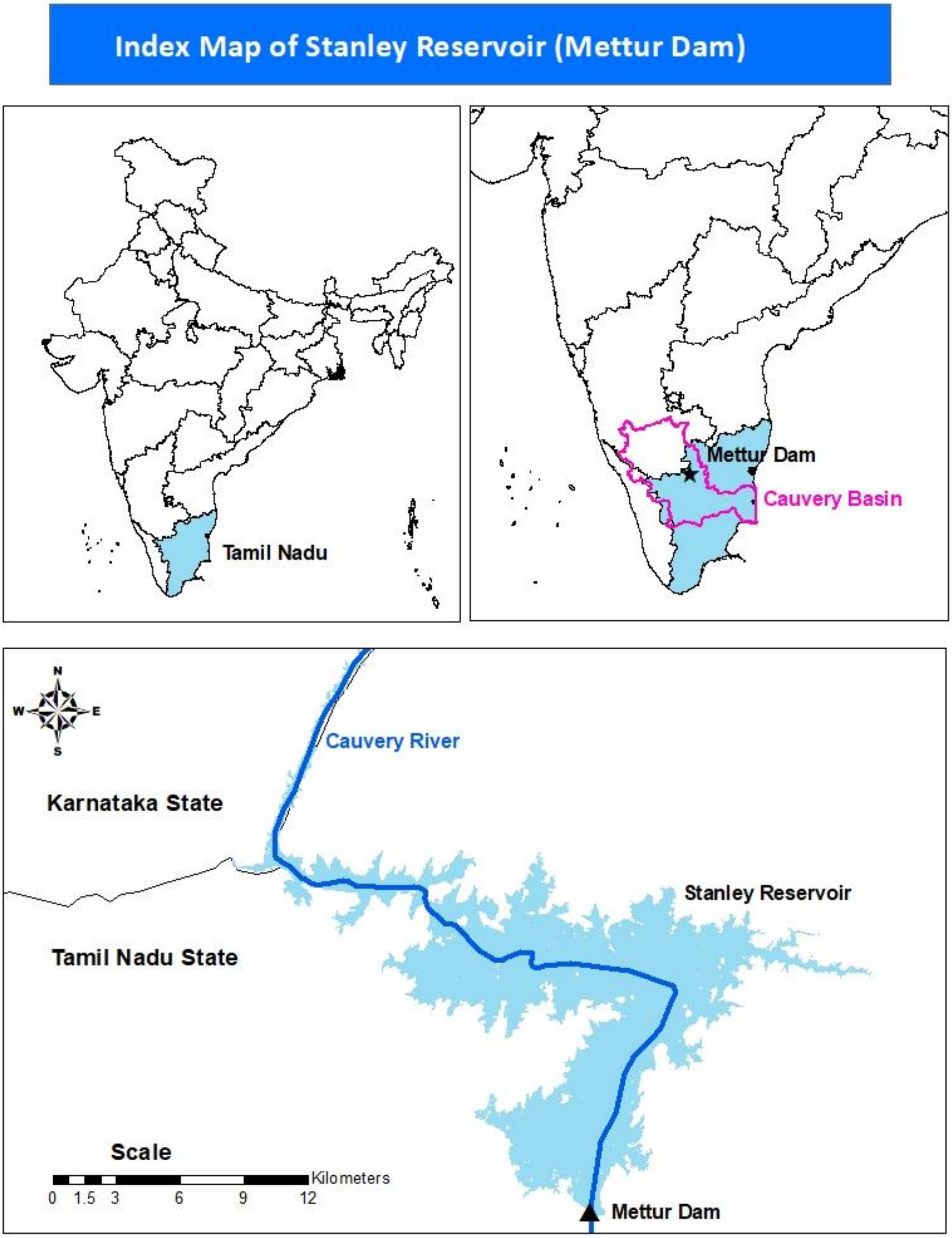


Fig. 4: Index map of the Stanley Reservoir

8. DATA USED

8.1. SATELLITE DATA

Microwave data from Sentinel 1A for nine (9) dates have been used in the analysis. Table 1 depicts the date of pass of satellite along with elevation observed on that date.

Table – 1: Date of pass for satellite data

Satellite	Date of Pass	Elevation (m)
Sentinal 1A	10/06/2018	216.353
Sentinal 1A	22/06/2018	219.642
Sentinal 1A	04/07/2018	223.138
Sentinal 1A	05/02/2019	225.692
Sentinal 1A	12/01/2019	227.478
Sentinal 1A	31/12/2018	230.49
Sentinal 1A	01/11/2018	234.105
Sentinal 1A	26/09/2018	236.101
Sentinal 1A	28/07/2018	240.889

8.2. FIELD DATA

The following field data have been obtained from project authorities:

Salient features of Stanley 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. For stanley reservoir studies, multi-date Sentinel 1 (9 nos. imageries) is used for the analysis. Image processing with SNAP software and 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 from Sentinel 1 satellite corresponding to reservoir area obtained from USGS Earth Explorer was loaded on the system. The Sentinel-1 mission is a constellation of two polar-orbiting satellites (Sentinel-1A and Sentinel-1B), that operate day and night, sensing with a C-band synthetic aperture radar instrument operating at a centre frequency of 5.405 GHz, allowing the acquisition of imagery regardless of weather and illumination conditions. Sentinel-1 satellite constellations acquire Synthetic Aperture Radar (SAR) data in single or dual polarization with a revisit time of 6 days. A series of standard corrections was applied to the data using SNAP software to apply a precise orbit of acquisition, remove thermal and image border noise, perform radiometric calibration, and apply range Doppler and terrain correction.

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. The technique adopted for water-spread area estimation are as follows:

- SAR data Pre-processing using Sentinel Application Platform (SNAP)
- Thresholding using ARC-GIS

9.2.1. SAR DATA PRE-PROCESSING USING SNAP

The open-source Sentinel Application Platform (SNAP) Toolkit developed by European Space Agency was used for SAR data pre-processing. Sentinel-1 intensities from high-resolution Level-1 ground range detected products (10 m; GRDH) were calibrated, speckle-filtered, and geometrically corrected using Range Doppler Terrain Correction. Specifically, the improved Lee-Sigma single product speckle filter with a window size of 7 by 7 was used to reduce speckle noise. Terrain correction were conducted using the recently released STRM 1 arc-second HGT digital elevation model (DEM) and UTM/WGS84 (Automatic) Map projection was used wherein SNAP automatically selects the required UTM zones.

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 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.

Water spread areas are extracted for all the scenes. Fig. 6 shows Sentinel 1A/1B images of different dates and Fig. 7 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 i.e. (10m x 10m) in case of Sentinel 1 imagery. 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)	Water Spread Area (sqkm)
10/06/2018	216.353	31.8348
22/06/2018	219.642	42.9251
04/07/2018	223.138	60.0924
05/02/2019	225.692	68.8936
12/01/2019	227.478	76.0728
31/12/2018	230.49	89.5095
01/11/2018	234.105	106.39
26/09/2018	236.101	116.606
28/07/2018	240.889	138.292

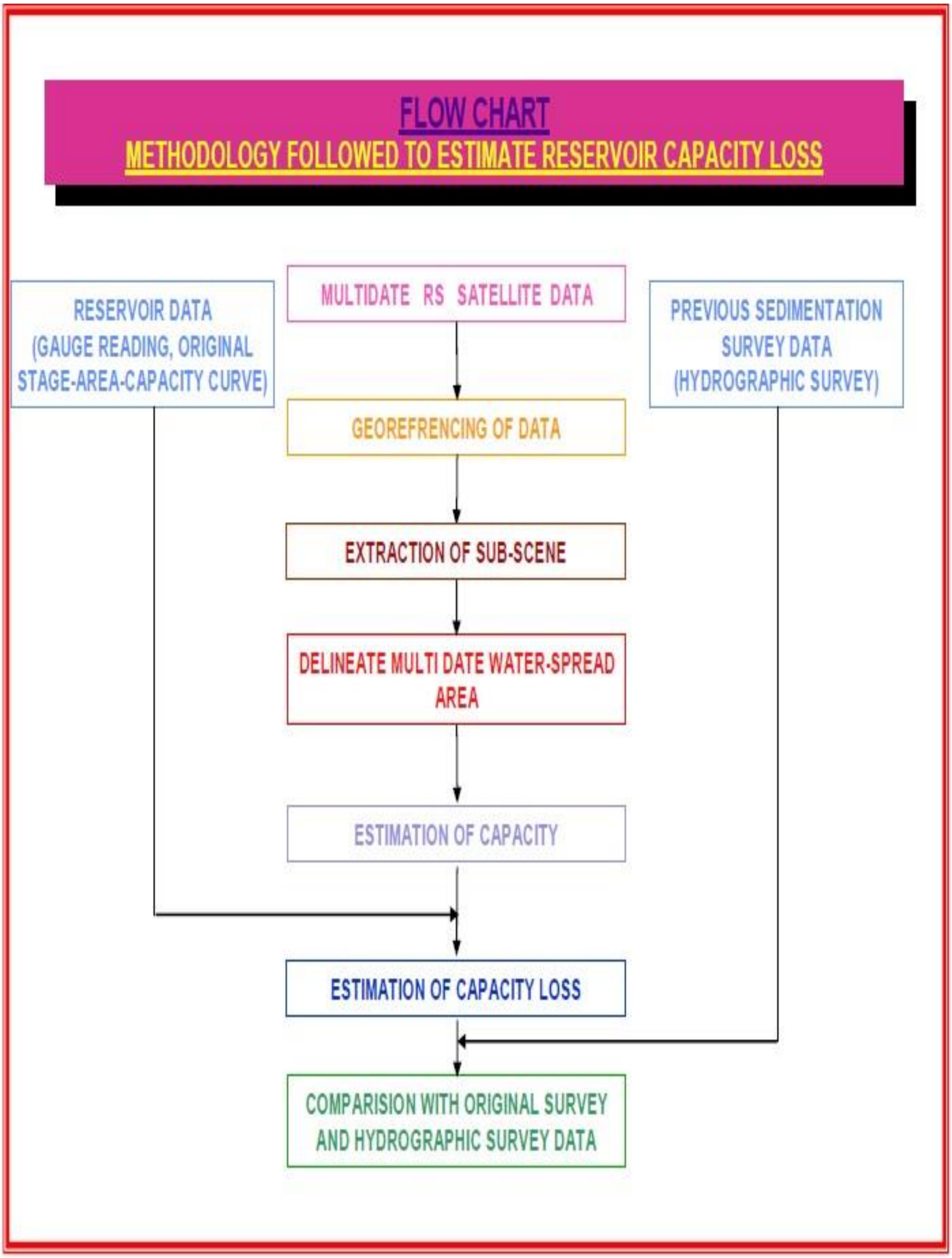


Fig 5 : Flow chart showing methodology followed to estimate reservoir capacity loss

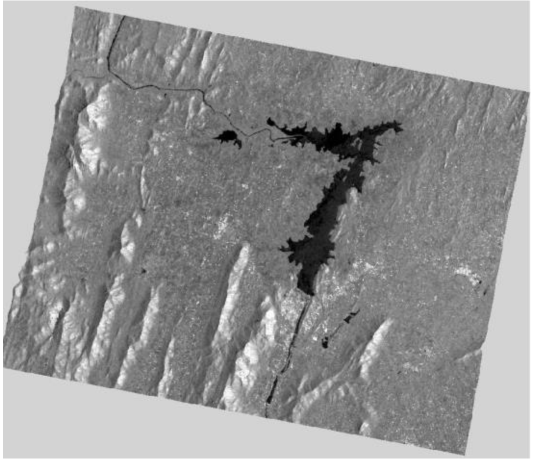
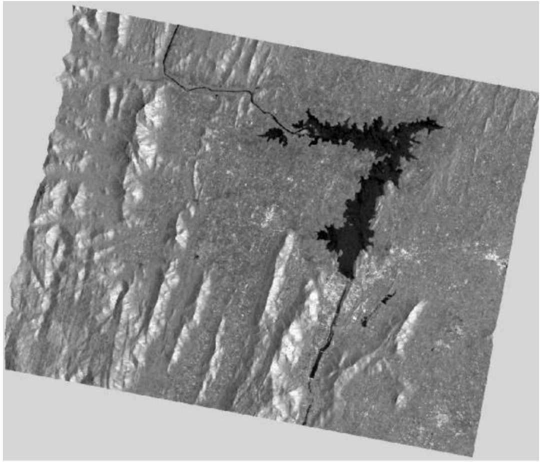
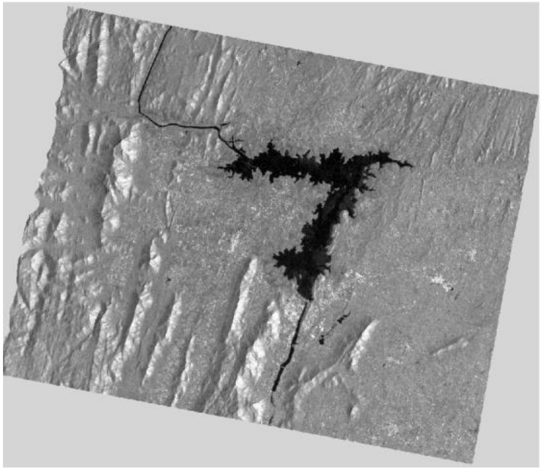
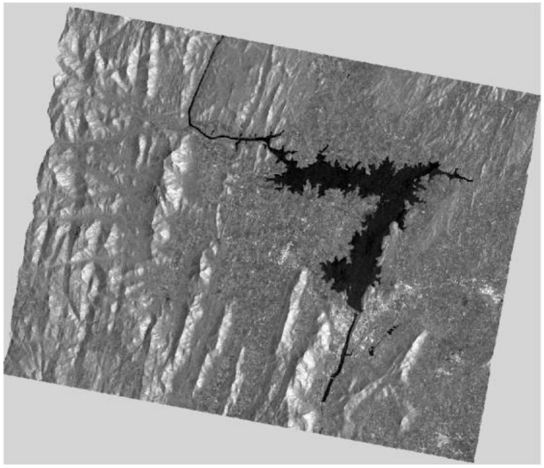
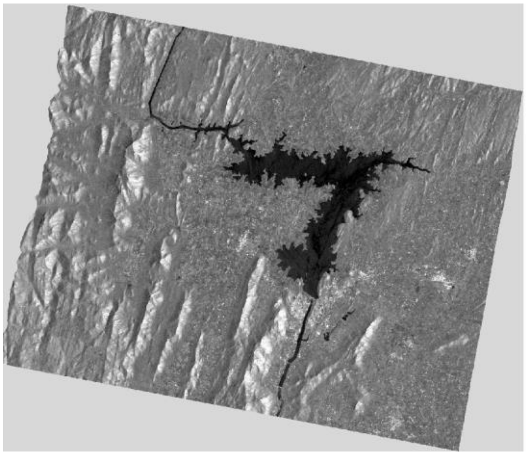
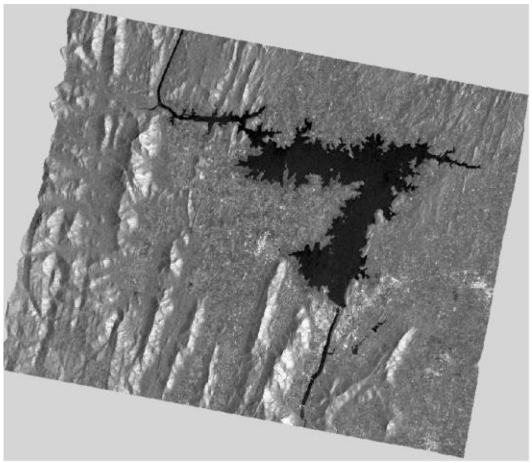
	
10-June-2018 (216.353 m)	**22-June-2018 (219.642 m)**
	
04-July-2018 (223.138 m)	**05-Feb-2019 (225.692 m)**
	
12-Jan-2019 (227.478 m)	**31-Dec-2018 (230.490 m)**

Fig 6 : Sentinel 1 SAR imageries showing water spreads at different dates

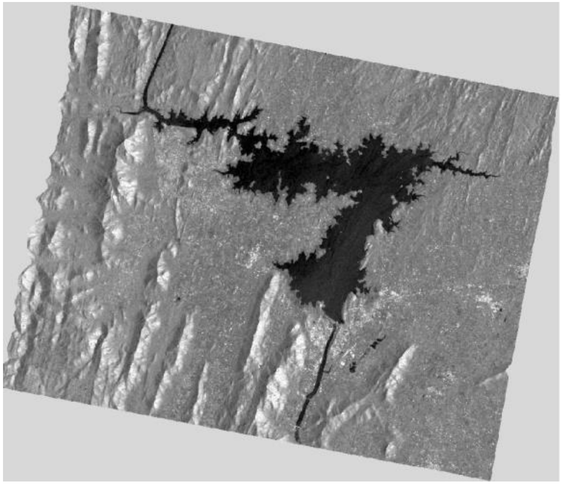
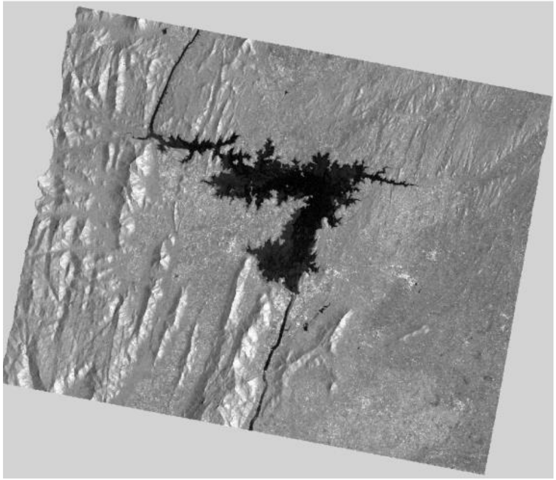
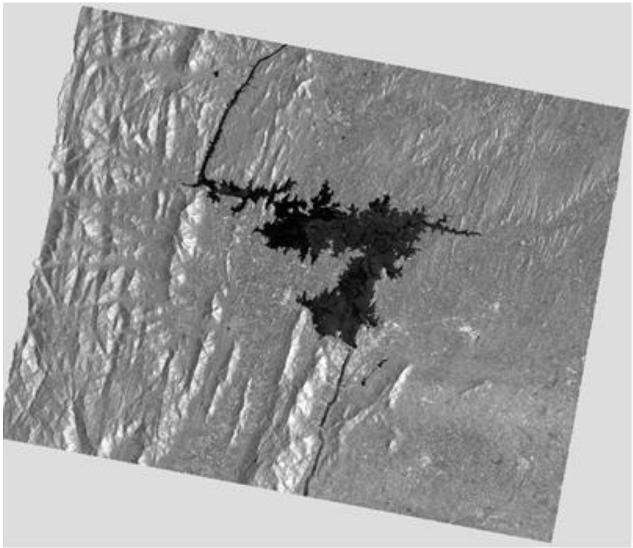
	
01-Nov-2018 (234.105 m)	**26-Sep-2018 (236.101 m)**
	
28-July-2018 (240.889 m)	

Fig 6 : Sentinel 1 SAR imageries showing water spreads at different dates

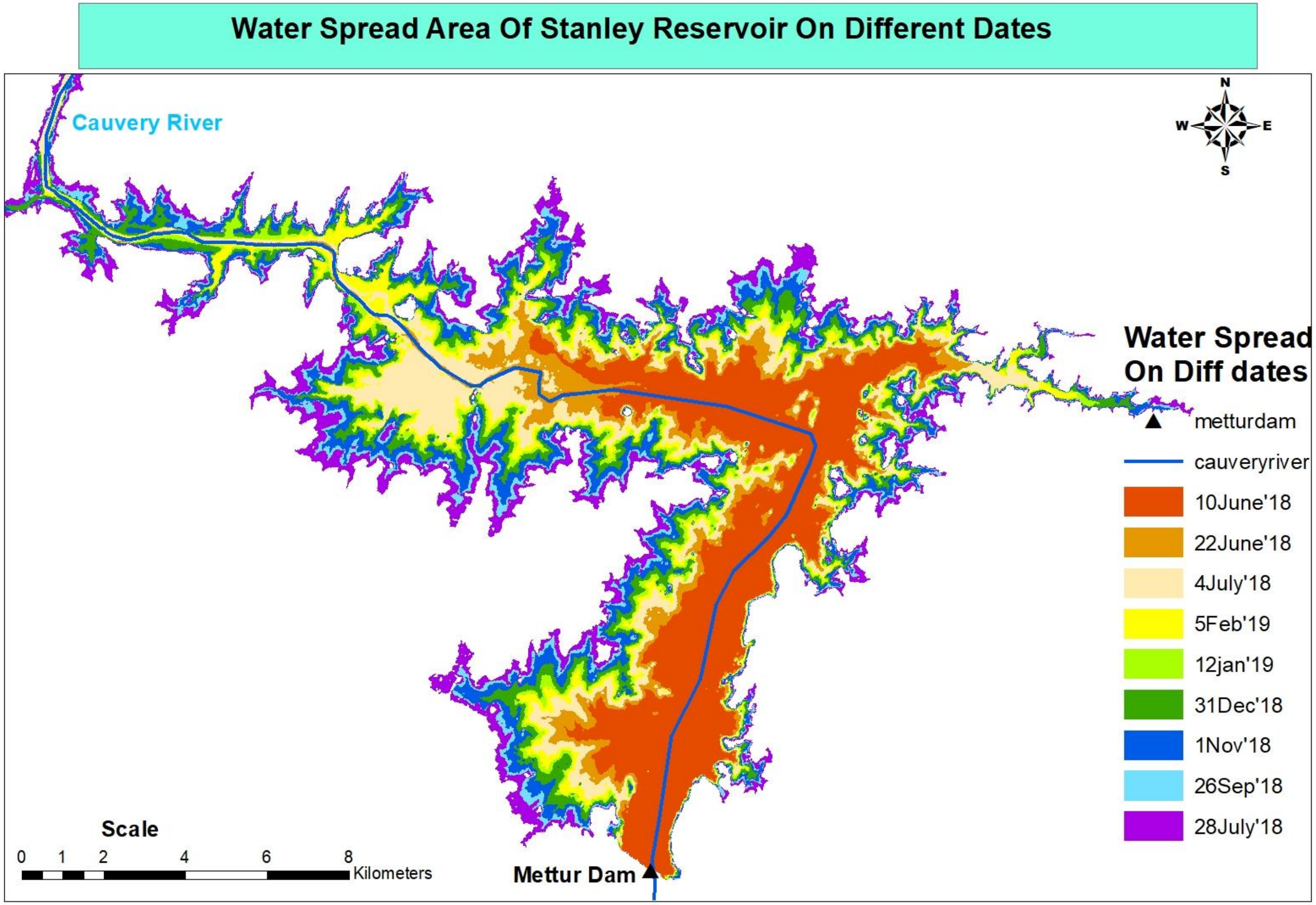


Fig. 7: Water Spread Area of Stanley Reservoir on different dates

The Satellite Images for the Stanley reservoir have been obtained from Copernicus Open Access Hub that provides complete, free and open access to all sentinel mission data. The analysis has been carried out using **Sentinel Application Platform** (SNAP) and Digital Image Processing software Arc GIS. The digitally processed images of Stanley Reservoir showing its water spread area for nine overpass dates such as 10-June-18, 22-June-18, 04-July-18, 05-Feb-19, 12-Jan-19, 31-Dec-18, 01-Nov-18, 26-Sep-18 and 28-Jul-18 are shown in fig. 7.

The water elevation 240.889 m for 28-Jul-18 is near the Full Reservoir Level (FRL) of 240.79 m. The Water elevation 216.353 m for 10-June-18 is below the Minimum Drawdown Level (MDDL) of 219.456 m and above Dead Storage Level (DSL) of 204.216 m.

9.3. Estimation of Reservoir Capacity

Area elevation curve has been plotted using these above nine(9) water-spread areas for different water level in the reservoir and best-fit polynomial equation of third order as given below have been derived.

$y = -0.0004x^3 + 0.0494x^2 + 2.6733x - 7.4768$

$R^2 = 0.9993$

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-8. 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

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

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 &

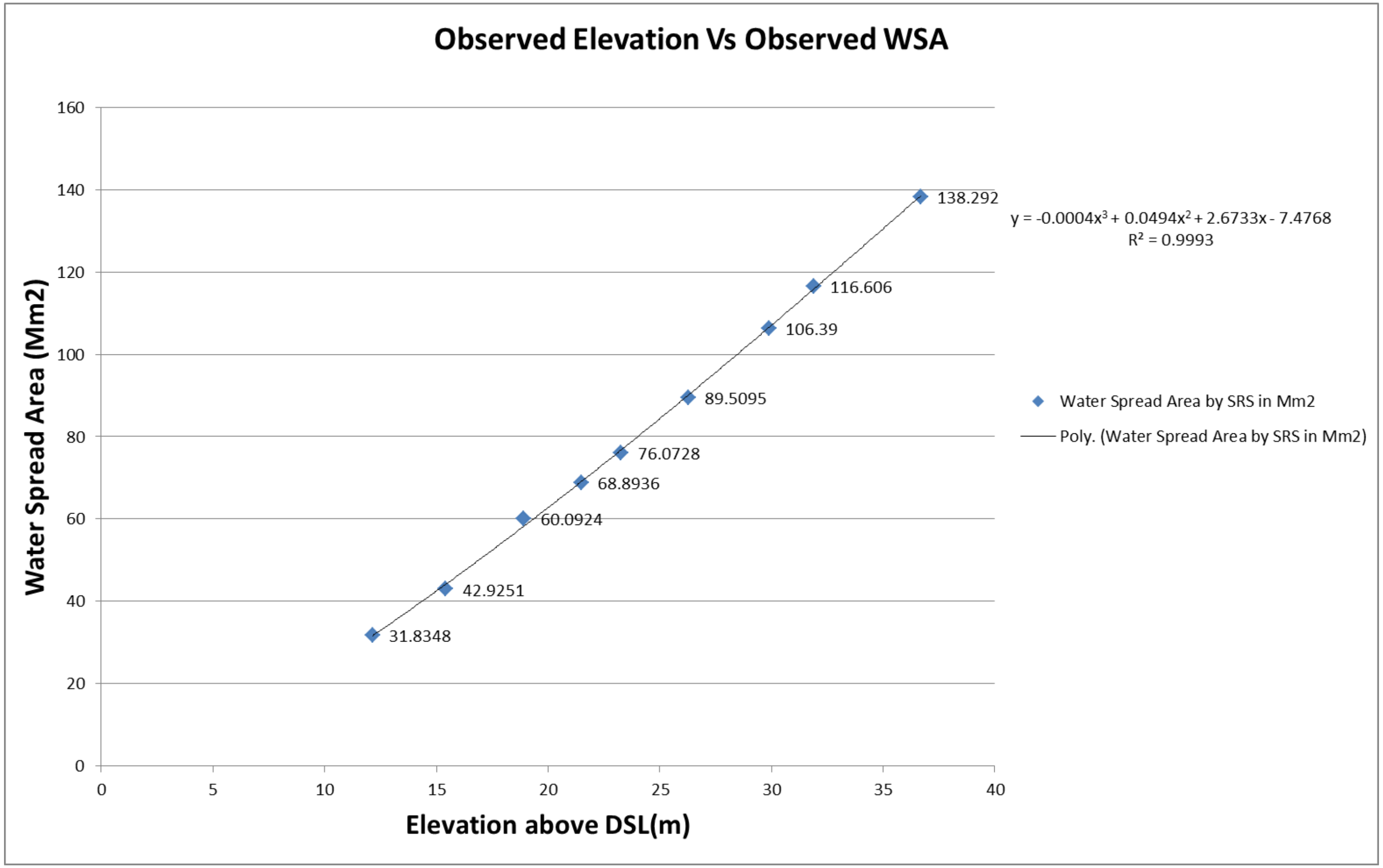


Fig. 8: Observed elevation vs Observed WSA of Stanley Reservoir

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 the 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-9 and Fig-10 respectively.

Table-3: Aerial extent of reservoir at regular interval (1.0m) using SRS Survey 2019

Reservoir water level in Metre		Water spread area by trend line (Mm^2)	Segmental Live Capacity (MCM) by SRS technique	Cumulative Live Capacity (MCM) by SRS technique 2019
DSL	204.216	0	0	0
	205	0	0	0
	206	0	0	0
	207	0.339881219	0	0
	208	3.324567286	1.575814441	1.575814441
	209	6.398962154	4.778626759	6.3544412
	210	9.560665821	7.927095429	14.28153663
	211	12.80727829	11.14449368	25.42603031
	212	16.13639956	14.43982286	39.86585318
	213	19.54562962	17.81380786	57.67966103
	214	23.03256849	21.26526213	78.94492317
	215	26.59481616	24.79235666	103.7372798
	216	30.22997262	28.39299571	132.1302755
	217	33.93563789	32.06495636	164.1952319
	218	37.70941196	35.80594869	200.0011806
	219	41.54889483	39.61364473	239.6148253
MDDL	219.456	43.32197511	19.34939153	258.9693612
	220	45.45168649	43.48569358	283.1005189
	221	49.41538696	47.41972988	330.5202488
	222	53.43759623	51.41337874	381.9336275
	223	57.51591429	55.46425881	437.3978863
	224	61.64794116	59.56998424	496.9678706
	225	65.83127683	63.72816595	560.6960365
	226	70.0635213	67.93641248	628.632449
	227	74.34227456	72.19233063	700.8247796
	228	78.66513663	76.49352588	777.3183055
	229	83.0297075	80.83760267	858.1559082

	230	87.43358716	85.22216465	943.3780728
	231	91.87437563	89.64481485	1033.022888
	232	96.3496729	94.10315579	1127.126043
	233	100.857079	98.59478961	1225.720833
	234	105.3941938	103.1173181	1328.838151
	235	109.9586175	107.6683428	1436.506494
	236	114.54795	112.245465	1548.751959
	237	119.1597912	116.8462859	1665.598245
	238	123.7917413	121.4684065	1787.066651
	239	128.4414002	126.1094275	1913.176079
	240	133.1063678	130.7669498	2043.943029
FRL	**240.79**	**136.8009382**	**106.6100564**	**2150.553085**

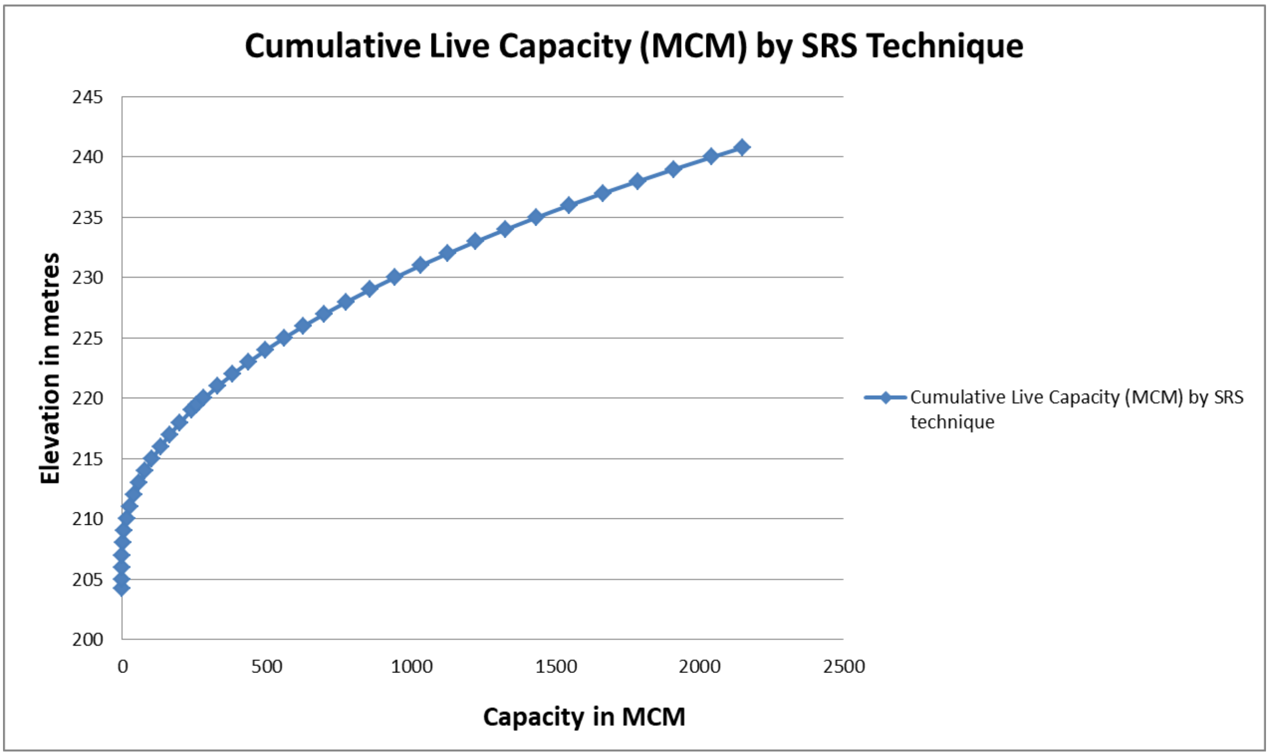


Fig. 9: Modified live capacity - elevation curve (SRS technique)

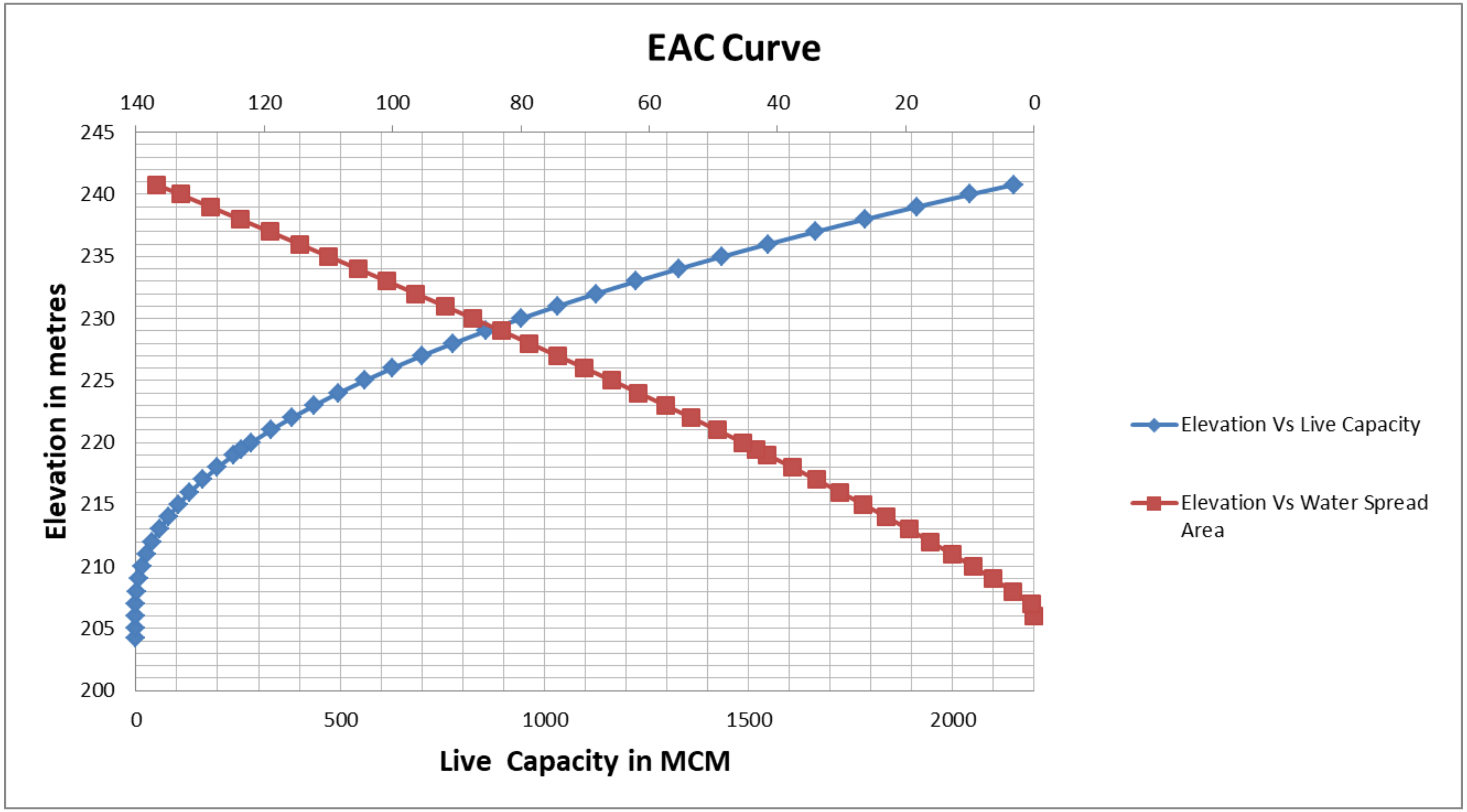


Fig. 10: Elevation – Area- Capacity Curve

9.4. Comparison with Original and Previous Surveys

Comparison of Live storage capacity of this SRS survey at various elevations cannot be done with the original (1934) and hydrographic surveys (1978,84) since elevation area tables for these surveys are not available

Mettur dam was completed in 1934 and its original gross and live storage capacity were reported as 2708.764 MCM & 2646.75 MCM respectively.

The first hydrographic capacity survey was conducted in 1978. The gross capacity was worked out to be 2264.32 MCM. In 1984, it was 2175.43 MCM when another survey was conducted

In the present study, it is found that live capacity of the Stanley reservoir in 2019 is 2150.55 MCM witnessing a live storage loss of 496.19 MCM (i.e. 18.75 %) in a period of 85 years during 1934 to 2019. This accounts for live capacity loss of 0.22% per annum since 1934. Live storage has not been evaluated separately in the above two hydrographic surveys

10. RESULTS AND DISCUSSIONS

The loss in live storage capacity of the reservoir due to sedimentation since original survey (1934), hydrographic survey (1978, 1984) is shown below.

Table – 5 : Storage Capacity loss due to sedimentation as per previous surveys

	Original Survey (1934)	**Hydrographic Survey (1978)**	**Hydrographic Survey (1984)**	**SRS (2019)**
Capacity (MCM)	2708.764 (Gross) 2646.744 (Live)	2264.32 (Gross)	2175.43 (Gross)	2150.55 (Live)
Loss in Capacity since 1934 (MCM)		444.44 (Gross)	533.33 (Gross)	496.19 (Live)
% Live capacity loss (since 1934)		-	-	18.75
Annual % live capacity loss		-	-	0.22

*Live storage has not been evaluated separately in the above two hydrographic surveys.

The live storage capacity of Stanley reservoir as per present study is found to be 2150.55 MCM for the year 2019. As per original survey conducted in 1934 the live storage capacity was 2646.74 MCM and as per hydrographic survey conducted in 1978, 1984 the gross storage capacities were 2264.32 MCM & 2175.43 MCM.
Modified elevation-area-capacity table worked out by the present study is given in Table 3.

11. CONCLUSION

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

1. The live storage capacity of Stanley reservoir has been found to be 2150.55 MCM in 2019.
2. Total loss in live storage capacity since reservoir began operation in 1934 is 496.19 MCM i.e. 18.75 % loss in live stoarge capacity over a period of 85

years which accounts for 0.22 % loss in live storage capacity every year.

3. 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.
4. 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.
5. **Capacity estimation using Microwave remote sensing technology has the advantage that cloud-free imageries are available throughout the year at frequent interval as they are not affected by weather or illumination conditions.**

12. 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. Ground truth verification of boundary pixels is not possible due to continuous variation in reservoir levels that prevents correlating field observation of reservoir boundary with satellite data.

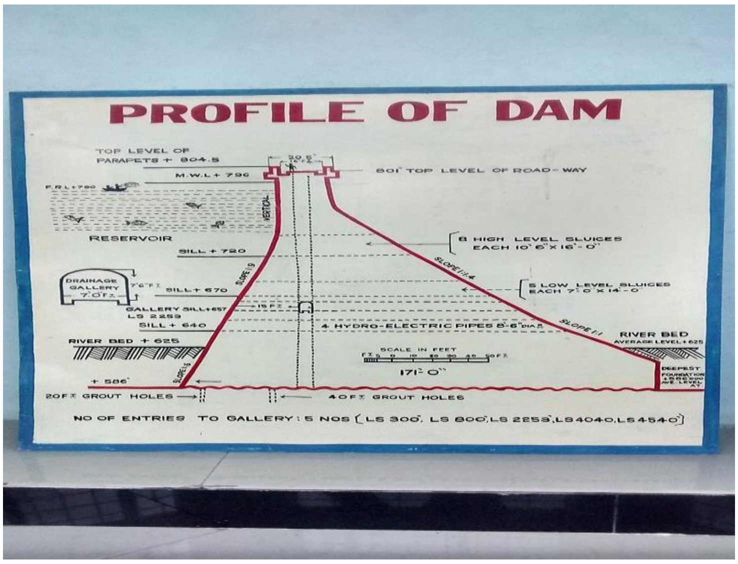
SALIENT FEATURES OF STANLEY (METTUR DAM) RESERVOIR

I LOCATION

1 State	:	Tamil Nadu
2 District	:	Salem
3 Village	:	Nayambadi
4 River	:	Cauvery
5 Site of Dam	:	On river Cauvery, receives inflow from its own catchment Area, Kabini Dam & Krishna Raj Sagara Dam located in Karnataka located at 11° 48′ 00″ N Lat & 77° 48′ 00″ E Long

II RESERVOIR

1 Full Reservoir Level	:	+240.79 M
2 Maximum Water Level	:	+242.62 M
3 Live Storage at FRL	:	2150.55 MCM(Current) & 2646.74(Original)
4 Water Spread Area at FRL	:	136.80 sq.km



Cross-section of Dam

PHOTOGRAPH OF RESERVOIR

Photo 1: Mettur Dam & Stanley Reservoir

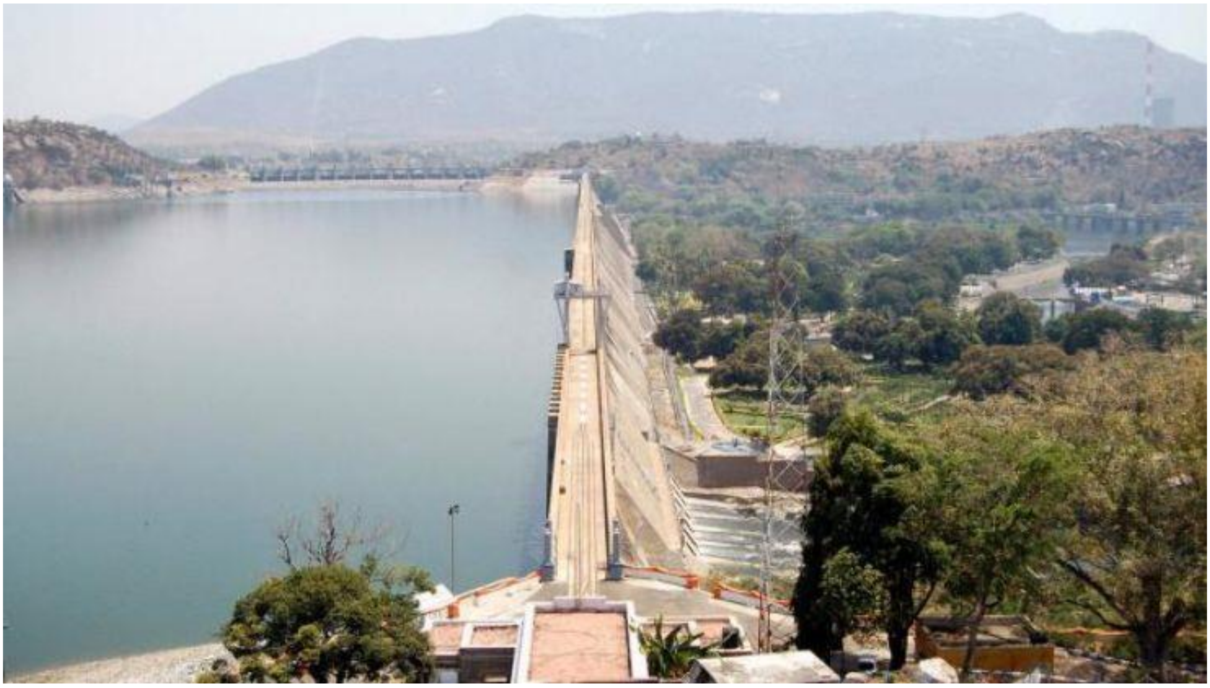


Photo 2: Mettur Dam & Stanley Reservoir

Photo 3: Mettur Dam & Stanley Reservoir

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