# Assessment of Sedimentation in Nizamsagar Reservoir Using Digital Remote Sensing Technique

**D.S. Rathore[1], Anju Chaudhary[1] and U.V.N. Rao**

*[1] National Institute of Hydrology, Roorkee- 247667, India*
*[2]National Institute of Hydrology, Kakinada, India*
*e-mail :dsr@nih.ernet.in*

## ABSTRACT

As per recommendations of Working Group for National Action for Reservoir Sedimentation Assessment, National Institute of Hydrology has taken up study on sedimentation for 25 reservoirs in India during X plan period using remote sensing technique. One such study for Nizamsagar reservoir in Godavari basin in Maharashtra for year 1930- 2006 is described here. Reservoir's original utilizable and gross volumes were 841.18 and 375.55 M m3 respectively. Minimum draw down level (MDDL) and full reservoir level (FRL) for reservoir are and 426.87 m respectively. Linear Imaging Self Scanning (LISS)- III data of Indian Remote Sensing Satellites (IRS) 1C and 1D, covering elevation range between 415.8 and 427.3 m, were used. Normalized Difference Vegetation Index (NDVI) and supervised classification techniques were used to determine water spread area. Revised live storage capacity was 375.55M m3. The silt index for the live storage area was 2.82 ha m (100 km2 year)-1 (0.73 % of live storage or 6.13 M m3 year-1). Total live storage lost in sedimentation was 465.63 M m3 (55.4 % of gross storage).

## INTRODUCTION

Estimated utilizable water in the country is 1122 BCM, of which 690 BCM is the surface water component. This leads to 1022.7 cum per capita utilizable water. Availability of water is not uniform in space and time. Temporally, both seasonal and annual variability are present. Thus, it is required to manage water resources through construction of dams. Storages conserve water, provide protection from floods, generate power and provide many other benefits. Till date nearly 4050 large dams (capacity larger than 10 Mcum) are constructed in India and another 475 dams are under construction.

Reservoirs formed due to impoundment are subject to sediment deposition in their storage areas. Thus, provisions of extra storage are made for deposition of sediment in the reservoirs, so that the benefits do not get reduced fast enough. Reservoirs in India lost about 0.5 to 1.5 per cent of their capacity annually, while some of them lose over 2 per cent each year. Reservoir sedimentation problem is classified as insignificant, significant or serous on the basis of the ratio of Expected_average annual volume of sediment deposition to the Gross capacity of the reservoir expressed in percentage. sedimentation problem for ratio less than 0.1, between 0.1 to 0.5 and more than 0.5 as classified as insignificant, significant and serious respectively.

Once reservoirs are formed, capacity surveys are required due to two reasons. Modified capacity tables and sedimentation rates are useful for modifying reservoir operation and taking suitable measure for reducing sedimentation in the reservoirs.

1. For reservoirs came in to existing in early years, enough data were not available at their planning stage and thus assumed sedimentation rate may not be valid.
2. Both river sediment inflows and reservoir sedimentation data as required to be incorporated in reservoir planning as per IS: 12182, 1987. Thus, there is a need to enrich database for India reservoir so that improved future planning may be adopted.

As per the recommendation Reservoir Sedimentation Committee of Ministry of Agriculture and Irrigation (Department of Irrigation), Government of India (1982), capacity surveys on regular intervals of once in 5 years for all major reservoirs should be carried out by the project authorities (Mahto and Patil 2005). However, in practice surveys are conducted in interval of 2 to 15 years. If practicable, interval for sedimentation surveys can be varied for two reasons:

1. Sedimentation rates are observed to be higher in first 15- 20 years and reducing thereof.
2. Reservoirs are built in upstream of existing reservoir, thus limiting sediment inflow in to the downstream reservoirs.

Many sedimentation surveys for reservoirs were carried out in past. In 1958, twenty-eight reservoirs were surveyed by organizations namely, Karnataka Engineering Research Station (KERS); Directorate of Irrigation Research, Bhopal; Maharashtra Engineering Research Institute (MERI); Uttar Pradesh Irrigation Research Institute (UPIRI) and Andra Pradesh Engineering Research Institute (APERL). Another 30 reservoirs were surveys in 8th plan under a scheme launched by Central Water Commission (CWC). Various state government agencies also carried out surveys time to time (Mahto and Patil 2005). Satellite remote sensing based surveys were completed for 124 reservoirs in X plan by CWC, National Institute of Hydrology (NIH), Central Water and Power Research Station (CW & PRS), and Regional Remote Sensing Service Centre (RRSSC), Jodhpur, as recommended by the Working Group for National Action for Reservoir Sedimentation Assessment. Study of one of these reservoirs namely, Nizamsagar is described here.

For reservoir sedimentation surveys, conventional and modern hydrographic surveys, exposed reservoir-bed surveys and remote sensing techniques are utilized. In conventional surveys theodolite, plane table, sextant, range finders, sounding rods, echo-sounders and slow-moving boat etc. are used. In modern hydrographic surveys utilizing high speed boats, global positioning systems, echo sounders and mapping softwares was introduced in 8th plan period by CWC. Remote sensing technique utilizes frequently sensed images to obtain water spread area of reservoir.

Conventional hydrographic surveys are less accurate and time consuming. Modern hydrographic surveys are more accurate and faster. Exposed reservoir-bed surveys are time consuming, expensive and possible only in drought years. Satellite remote sensing surveys are cheaper and faster. Satellite data for post monsoon period are utilized. For this period cloud free images are normally available. Water level fluctuation is reservoir may not be much and in some instances multiple year remote sensing data may be needed to cover full water level range between MDDL and FRL. Using remotely sensed data, live storage capacity survey can only be done. Satellite remotely sensed data are used in the present study.

Digital image processing was widely utilized with satellite remote sensing data for reservoir sedimentation. Techniques e.g. density slicing, supervised classification (Manavalan et al. 1993), ratio (Gupta et al 1998), water index (Rathore et al. 2006), rule based classification (Goel and Jain 1996), NDWI (Goel et. Al 2000) etc. In Malaprabha and Bhadra threshold for water in infrared band varied from 10 to 31 digital number (DN) for LISS- II and 21- 35 DN for TM data. Rule based classification using 'water index' and radiances in near infrared band were used. Goel and Jain (1996) used thresholds for infrared DN and a signature rules infrared and red DN smaller than blue and green DN for Dharoi reservoir. Goel et al. (2000) used threshold for Normalized Difference Water Index (NDWI)>= 0.44 and rule as above. Here, NDVI and supervised classification techniques are used.

## STUDY AREA AND DATA

Nizamsagar is located on Manjira a major right bank tributary of Godavari (Fig. 1). Manjira rises in Balaghat range of hills in Bidar district of Maharashtra. The tributaries having their sources in the uplands of Osmanabad and Bidar districts join the main stream. River flows through Medak, Nizamabad and Nanded districts. There are two physical regions in the sub basin namely high lands of Bhir and Osmanabad districts and plains from Bidar districts to the confluence of Manjira with the Godavari. Average annual rainfall is nearly 80 cm. Rainfall occurs mainly through south- west monsoon. Soils in the catchment area of Nizamsagar projects are medium black (68%), Red sandy (16%), laterite (11%) and shallow black (5%). Deccan trap (Basalt) consists of 76% of the catchment area. Remaining area has ancient crystallines and metamorphics.

Nizamsagar was constructed during 1923 to 1930. Original capacity of the reservoir was 841.18 M cum. From hydrographic survey conducted during 1967, the capacity was estimated to be equal to 402.91 M cum. This indicated a loss of 52.1 % capacity. In order to compensate the loss of storage, FRL of the reservoir was raised by 1.37 m i.e. from 426.87 m to 428.24 m in the year 1978 to increase the capacity by 150 M cum. The capacity of reservoir increased to 496.70 M cum.

Manjira Barrage was constructed 80.5 km upstream of Nizamsagar. The Barrage drains 16770 sq. km catchment area and supplies water to Hyderabad and Secunderabad. Singur project is located 130 km upstream of Nizamsagar with storage capacity of 849.38 M cum. The project regulates releases to Nizamsagar and helps in reducing the rate of siltation.

**Table 1: Satellite remotely sensed data, reservoir elevation and area**

| Image date | Reservoir Elevation in m | Water spread Area sq. km |
|---|---|---|
| 15-Jan-05 | 415.8 | 4.15 |
| 2-Apr-04 | 418.1 | 8.91 |
| 21-Jan-04 | 421.7 | 26.42 |
| 10-May-06 | 424.2 | 54.06 |
| 3-Feb-06 | 425.8 | 78.91 |
| 17-Dec-05 | 427.3 | 93.40 |

During 1956- 57, reduction in capacity was realized by project authority. Thereafter, direct surveys of the contours on the periphery of the reservoir were conducted for reservoir water levels and capacity of reservoir was estimated to be 457.67 M cum in 1961. Subsequently, surveys were conducted during 1966- 67, 1975 and 1992.

IRS LISS-3 data were obtained from NRSA. Data were selected based on water level variation and availability of cloud free data. Drawdown during 2006 summer was 3 m only. There was less storage in the reservoir in year 2004. Thus, data for summer of 2004 were used for middle levels, data of summer of 2005 of lower levels and data of summer of 2006 were used for higher water levels. Satellite data used are given in Table

## METHODOLOGY

Satellite data were geo-referenced and digitally processed to extract water spread area. Two digitial processing techniques namely density slicing of NDVI images and supervised classification were used. Supervised classification/ manually editing techniques were used for relatively complex wet soil environment at higher water level images.

Spectral signatures of the objects indicate that reflectance of water decreases from visible to near infrared wavelengths. For soil, reflectance increases from visible to near infrared wavelengths. Vegetation has very high reflectance in near infrared wavelength. These spectral signatures results in very low NDVI for water compared to soil and vegetation classes.

Satellite data were georeferenced with less than one pixel root mean square (rms) error. NDVI was estimated using near infrared and red band digital numbers. FCC was displayed and corresponding to the water pixels a threshold for NDVI was obtained. This threshold was used to reclassify image as water and non water class. The threshold for images of 15 January, 2005, 2 April 2004 and 21 January 2004 were -0.202, -0.123 and -0.154 respectively. Pixels with NDVI lower than these thresholds were recoded to water pixels.

NDVI= (DN IR band- DN red band)/ (DN IR band+ DN red band)

For supervised classification, training samples were selected for water and non water classes. For classes e.g. water and fallow/ barren areas multiple samples were taken due to varied signatures in each of these classes. The maximum likelihood classifier was selected. The classified map was recoded as binary water image. Areas that were connected by very narrow channel in the periphery were disconnected from main body of water by recoding narrow channel as non water. Contiguous water area was obtained by clumping.

Water spread area was interpolated at 0.1 sq. km interval using linear interpolation. Thus estimated elevation- area table was used to find reservoir volume applying cone formulae.

$$V = \frac{H}{3}\left(A1 + A2 + \sqrt{A1 * A2}\right)$$

Where, V= Reservoir incremental volume between water spread area A1 and A2

H=Elevation difference for water spread areas A1 and A2.

Elevation- area- capacity curve and tables are given in Fig. 1, 2 and Table 2, 3 respectively. The thematic maps of water spread areas were overlaid to show incremental water spread areas (Fig. 3)

## RESULTS

As per remote sensing based study of sedimentation of Nizamsagar, storage up to 427.30 m is 414.81 M cum. Up to original FRL (426.87 m), the original and revised gross capacities are 841.18 and 375.55 M cum respectively. As per 1992 hydrographic survey, the dead storage capacity was very small, nearly 1.13 M cum and was assumed zero for remote sensing based revision in elevation- storage table. Loss in storage up to original FRL is given in table 4. Since, percent yearly loss in storage capacity lies between 0.5 and 1.0, the sedimentation is serious. Silt index was 2.82 Ha m (100 km2 year)-1. Design sedimentation rate was 1.16 M cum year-1. Actual sedimentation rate was nearly six times the design rate.

Differences in capacity estimation were observed between hydrographic and remote sensing based survey. Past hydrographic surveys in Nizamsagar were conventional hydrographic surveys. These surveys are less accurate compared to modern hydrographic surveys which utilize differential GPS, automated mapping etc. Average sedimentation rate will de reducing in future, since sediment inflow in to the reservoir is reduced due to construction of Singur reservoir in the upstream.

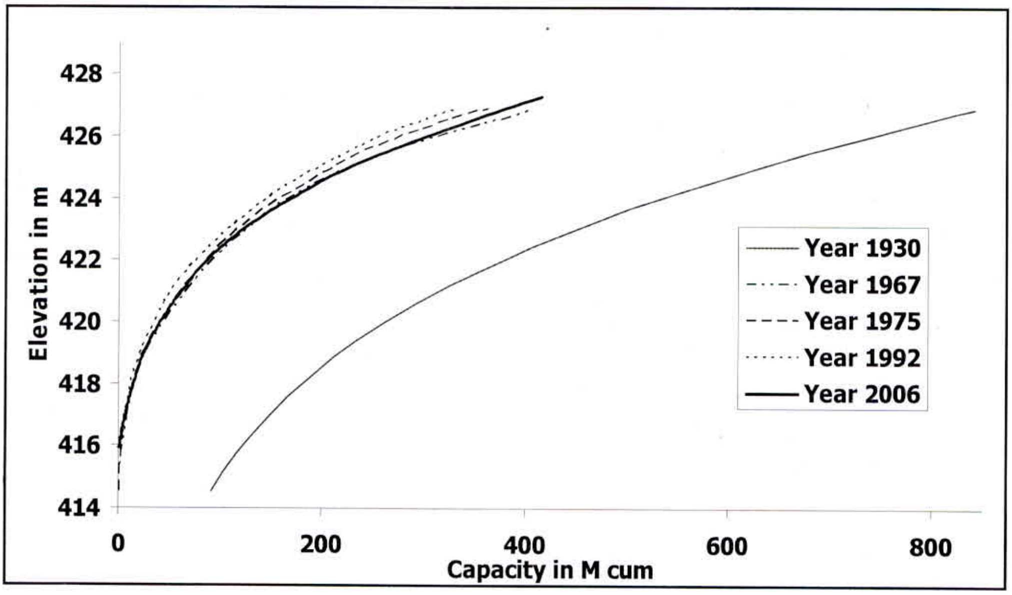


**Fig. 1 : Elevation- Capacity curve**

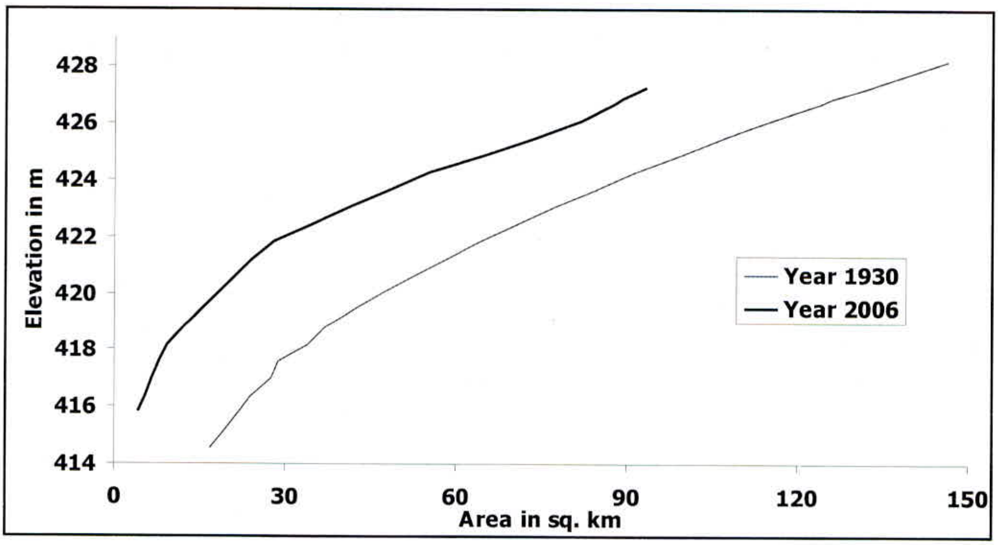


**Fig. 2 : Elevation- Area curve**

**Table 2: Elevation- capacity table**

| Elevation in m | Capacity in M.cum | | | | |
|---|---|---|---|---|---|
| | Year 1930 (Original) | Year 1967 (Hydrographic) | Year 1975 (Hydrographic) | Year 1992 (Hydrographic) | Year 2006 (Remote Sensing) |
| 414.53 | 91.36 | 0.71 | 0.46 | 0.00 | 0.00 |
| 415.14 | 103.05 | 1.67 | 1.09 | 0.00 | 0.00 |
| 415.75 | 116.31 | 3.35 | 2.90 | 0.00 | 0.00 |
| 416.36 | 131.24 | 5.59 | 4.44 | 2.27 | 2.65 |
| 416.97 | 147.91 | 8.18 | 7.42 | 6.00 | 6.27 |
| 417.58 | 166.36 | 11.86 | 11.22 | 10.00 | 10.67 |
| 418.19 | 186.82 | 17.04 | 15.64 | 12.99 | 15.84 |
| 418.80 | 209.30 | 24.22 | 22.07 | 10.00 | 22.45 |
| 419.40 | 234.16 | 33.61 | 30.97 | 26.00 | 30.71 |
| 420.01 | 261.89 | 44.72 | 41.17 | 34.48 | 40.91 |
| 420.62 | 292.90 | 57.98 | 52.88 | 44.00 | 52.92 |
| 421.23 | 327.32 | 71.86 | 66.37 | 56.00 | 66.74 |
| 421.84 | 365.33 | 87.85 | 82.72 | 73.01 | 82.43 |
| 422.45 | 407.24 | 106.31 | 98.94 | 85.01 | 101.55 |
| 423.06 | 453.02 | 127.56 | 118.71 | 102.01 | 124.78 |
| 423.67 | 503.12 | 152.19 | 147.89 | 139.77 | 152.12 |
| 424.28 | 557.41 | 180.44 | 172.72 | 149.98 | 183.59 |
| 424.89 | 616.22 | 216.50 | 203.88 | 183.97 | 220.21 |
| 425.50 | 679.96 | 263.88 | 237.86 | 225.96 | 262.61 |
| 426.11 | 748.43 | 320.52 | 283.17 | 263.48 | 310.51 |
| 426.72 | 822.10 | 402.91 | 334.13 | 319.96 | 362.27 |
| 426.87 | 841.18 | 402.91 | 362.40 | 332.52 | 375.55 |
| 427.30 | | | | 384.05 | 414.81 |
| 428.24 | | | | 496.70 | |

**Table 3 : Elevation- area table**

| Elevation in m | Area in sq km | |
|---|---|---|
| | Year 1930 (Original) | Year 2006 (Remote sensing) |
| 414.53 | 16.77 | - |
| 415.14 | 19.26 | - |
| 415.75 | 21.74 | - |
| 415.80 | 21.91 | 4.15 |
| 416.36 | 23.85 | 5.31 |
| 416.97 | 27.59 | 6.57 |
| 417.58 | 28.90 | 7.83 |
| 418.19 | 34.00 | 9.35 |
| 418.80 | 37.16 | 12.31 |
| 419.40 | 41.75 | 15.23 |
| 420.01 | 46.96 | 18.20 |
| 420.62 | 52.46 | 21.17 |
| 421.23 | 58.06 | 24.13 |
| 421.84 | 64.26 | 27.97 |
| 422.45 | 70.56 | 34.71 |
| 423.06 | 77.32 | 41.46 |
| 423.67 | 84.37 | 48.20 |
| 424.28 | 91.52 | 55.30 |
| 424.89 | 99.17 | 64.78 |
| 425.50 | 107.08 | 74.25 |
| 426.11 | 115.11 | 81.90 |
| 426.72 | 123.85 | 87.80 |
| 426.87 | 125.98 | 89.25 |
| 427.30 | 132.35 | 93.40 |
| 428.24 | 146.27 | - |

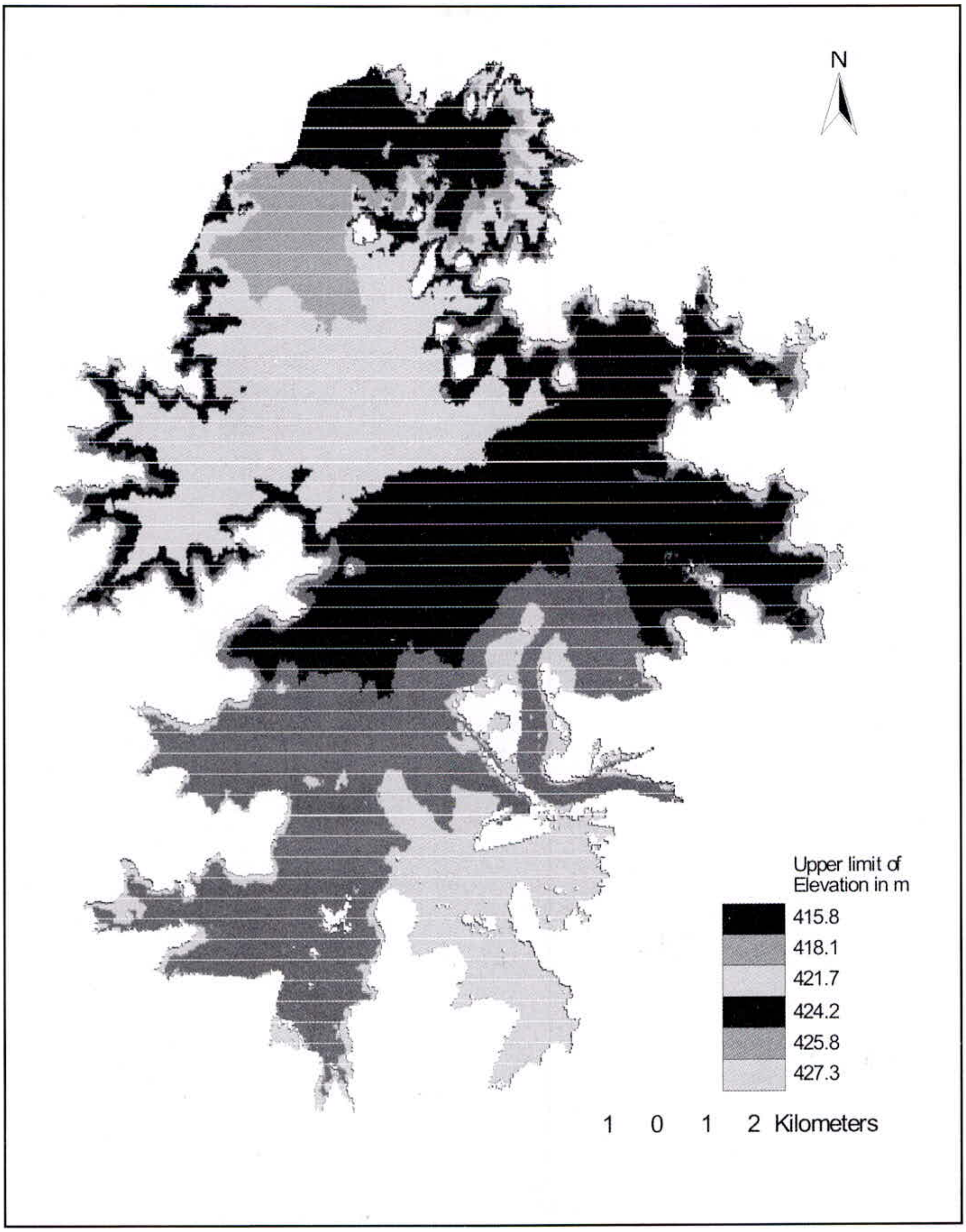


**Fig. 3 : Water spread area at different elevations**

**Table 4 : Reservoir sedimentation rate**

| Sedimentation of gross storage in units of | 1930- 2006 |
|---|---|
| M cum | 465.63 |
| M cum $year^{-1}$ | 6.13 |
| % of gross storage | 55.4% |
| % of gross storage $year^{-1}$ | 0.73% |
| Ha m (100 $km^2$ $year)^{-1}$ | 2.82 |

## CONCLUSION

High average sedimentation rate is observed in Nizamsagar reservoir is mainly due to higher rates in period prior to construction of Singur dam in the upstream. Higher average rate of sedimentation is also due to reason that the reservoir was constructed when very less data on reservoir sedimentation/ sediment inflow were available for planning. Current sedimentation rate could not be evaluated due to non availability of modern hydrographic survey/ remote sending surveys information. However, it is likely to be small due to construction of reservoir upstream of Nizamsagar. Thus, due to presence of reservoir upstream of Nizamsagar, life of latter reservoir will increase further. The results obtained will provide useful data for future planning of reservoirs in the region.

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## APPENDIX I FORMULAE USED

$$L_\lambda = L_\lambda(\min) + (L_\lambda(\max) - L_\lambda(\min)) * (Q_{CAL} / Q_{CAL}(\max))$$

Where,
Lë= Radiance in mw cm-2str-1 mm-1 for given DN
Lë(min)= Radiance in mw cm-2 str-1 mm-1 for minimum DN
Lë (max)= Radiance in mw cm-2 str-1 mm-1 for maximum DN
QCAL= Digital number (DN)
QCAL (max)= Maximum DN (255 for standard LISS- III products)

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

Where,
NDVI= Normalized Difference Vegetation Index
RED= Radiance in red band in mw cm-2 str-1 mm-1
NIR= Radiance in near infrared band in mw cm-2 str-1 mm-1

$$Area = a + bh + ch^2$$

(3)
Where,
Area = water spread area in ha
h= elevation in m
a, b, c= regression constants