CS-84

QUANTITATIVE ASSESSMENT OF SEDIMENT DISTRIBUTION IN THE TUNGABHADRA RESERVOIR USING SATELLITE IMAGERY

NATIONAL INSTITUTE OF HYDROLOGY
HARD ROCK REGIONAL CENTRE
BELGAUM

1991-92

CONTENTS PAGE

LIST OF TABLES

ABSTRACT

Concentration of suspended sediment is an important parameter for monitoring the effectiveness of in the reservoir. In order to map and assess the suspended sediment in the inland water body, Tungabhadra reservoir on Tungabhadra river in Krishna basin has been selected. The study has been carried out using Landsat MSS and IRS-1A-LISS-II images.

Visual interpretation techniques have been used to obtain the information on the location and extent of sediment distribution pattern in the water spread area of the reservoir. It has been possible to monitor the seasonal fluctuation of water to assess the volume of water in the reservoir as well as monitor the seasonal changes in the suspended sediment distribution pattern in the reservoir. Attempt has also been made to prepare area capacity curve.

Quantitative assessment of sediment deposit at various elevation levels of the reservoir were made taking water spread area from the satellite images and elevation levels from the KERS 1985 sedimentation survey report. The results indicated that the high concentration of sediment is observed at the western confluence of the Tungabhadra river and low concentration at the dam site.On the basis of the degree of sediment concentration,the reservoir could be divided into three major zones viz., very high at the river confluence, moderately at the fringes and low at the dam site.The area capacity curve derived for the area has been found to be in close agreement with that obtained from hydrographic survey. The computed average sedimentation rate of 6 ha.m/100 sq.km/year for this study compares well with that of observed rate of siltation of 6.48 ha.m/100 sq.km/year.

1.0 INTRODUCTION

A great amount of sediment is carried down to rivers, lakes, estuaries, bays, oceans annually. Soil is eroded mainly by water and winds, resulting in tremendous sediment movement into water courses by floods and storms. Highway construction, tillage of cropland, housing and urban development also yield a high volume of sediments. Other contributors are landfill channel and discharge of suspended solid contained in sewer, industrial wastes and ocean dumping of solid wastes and sludge.

Recent observations have brought to light an alarming fact that the reservoir sedimentation, resulting from degradation of watershed is on manifold rise compared to the rate that was assumed at the time these projects were designed.According to one estimate nearly 20% of the live storage capacity of the major and medium dams would be silted by the end of the century which would mean a loss of irrigation potential of about 4 M.ha (ISRO 1986). In other word,India will continue to lose an irrigation potential of almost 60,000 ha. every year due to siltation (CSE 1982).

The suspended material discharged by river into the reservoir,transports many pollutants and are the natural material that fill channel and reservoir capacity. The input of suspended material to reservoir is variable in concentration and composition from river to river, as well as changing with time in any particular river. The variation in average concentration is mainly related to seasonal changes in precipitation and runoff within the drainage basin of the river. The regions of extreme seasonal variation in precipitation and runoff also have the widest variation in suspended material concentration while the regions with reasonably steady climate have the least variation in suspended material concentration.

The composition of the suspended material discharged by rivers into reservoirs may vary, depending on the composition of the rocks and soils in the basin, the weathering climate to which these rocks and soils have been exposed and the energy of river to transport various sizes of material. The various minerals that make up the suspended material, all have different size distribution. Superimposed upon the inorganic fraction of the suspended material transported by river in the natural biologically produced material in the river generally amounting to only few milligram per litre of organic material.The cutting of forest, planning for formland and the multiplicity of construction projects associated with man's industrial and residental expansion have markedly increased the concentration and discharge of suspended material.Man is reponsible for the addition of natural material to rivers and reservoirs, such as solid sewage and industrial wastes in the form of metal,plastics, and wood etc.

The large sized sediments entering the reservoir are deposited near the mouth of the entering stream. These particles are trapped within the reservoir with near 100% efficiency. The finer sized sediments, clays, silts, and organic debris, remain in suspension and become mixed with the reservoir water, as the inflowing water are mixed with the existing impounded waters.

1.1 OBJECTIVES

- Mapping and assessment of sediment distribution pattern in Tungabhadra reservoir.
- To develop a methodology for the monitoring of suspended sediment in reservoir using remotely sensed data.

2.0 REVIEW:

The river flowing into the reservoir discharges large amount of silt, sand and clay, reducing the capacity of the reservoir.It is imperative therefore to evaluate the rate of sedimentation at the planning stage of hydropower structures. The Central Board of Irrigation and Power has taken up a series of systematic sedimentation survey of Tungabhadra reservoir to determine the rate of siltation.

During the period of 25 years (1960 to 1985) five sedimentation survey have been carried out in 1963,1972,1978,1981 and 1985.The recent sedimentation survey of 1985 computed 3166.74 M.Cu.m capacity at FRL 497.738 mtrs (1633 ft), and the quantity of silt deposited was 584.43 M.cu.m for a span of 32 years from 1953 to 1985.The annual rate of siltation was 18.26 M.cu.m/ year (6.48 ham/100 sq.km/year).As per the 1985 survey the loss in dead storage was 100% and the loss in live storage was 14.84% and the overall loss in the impounding capacity during 1985 of the reservoir compared to that of original capacity of 1953 was 15.58%.

The rates of siltation for different survey period viz 1953-1962,1953-1972,1953-1978,1953-1981 and 1953-1985 are given below.

S.No	Year	Capacity (M.cu.m)	Rate of silting (ha.m/100 sq.km/year)
1	1953	3751.17	17.90
	1963	3246.79	
	10 years loss is	504.38	
2	1953	3751.17	6.02
	1972	3428.60	
	19 years loss is	322.57	
3	1953	3751.17	5.94
	1978	3332.75	
	25 years loss is	418.42	
4	1953	3751.17	6.03
	1981	3275.68	
	28 years loss is	475.49	
5	1953	3751.17	6.48
	1985	3166.74	
	32 years loss is	584.43	

6	1972	3428.60	5.67
	1978	3332.75	
		-------	
6 years loss is		95.85	
7	1978	3332.75	6.75
	1981	3275.68	
		-------	
3 years loss is		57.07	
8	1981	3275.68	9.66
	1985	3166.74	
		-------	
4 years loss is		108.94	

The trend of siltation is about 6.1175 ha.m/100 sq.km/year. The annual rate of siltation is 0.4868 percent of the storage.

From the survey results it can be seen that there is large variation between assumed and observed rate of sedimentation. Hence it is necessary to have detailed knowledge about mechanism of sedimentation and the techniques for prediction of rate of sedimentation and measure to control the sedimentation.

Conventional methods used to measure the concentration of suspended sediments involve the collection and processing of discrete samples which require considerable labour at a given time and place in the field. A large amount of time and labour is also required for tedious analytical laboratory procedure.

The management of large reservoirs will be enhanced if information concerning the suspended sediment budget of the reservoirs is available at regular interval. This would further be aided if a relatively cheap, efficient and accurate means is available for determining the instantaneous suspended sediment load in large water bodies.

Remote sensing of reflected solar radiation can provide timely and repeated information concerning suspended sediment flow patterns in reservoirs. Studies have shown that quantitative relationship exists between suspended sediment concentration and reflected solar radiation (Weishlatt et al 1973; Yarger et al. 1974). Ritchie et al (1976) have shown a high correlation ($r = 0.90$) between the concentration of suspended sediments in surface water of reservoirs and the amount of reflected solar radiation. Besides monitoring the concentration of suspended sediments, the surface area of the impoundment may easily be determined by using remotely sensed data. By utilizing some usually available morphometric data, the surface area may be related to lake volume when lake volume is highly variable eg. flood control reservoirs.

Successful coupling of newly developed hydrodynamic models and digitally processed satellite data has made possible the mathematical modelling of sedimentation by correlating reflectance values with sedimentation rate (Khorram et al 1985., Ritchie et al 1988 and Choubey 1990) and also inventoring of watershed runoff potential thereby help taking steps to minimise sediment runoff and maximise clean water recharge.

3.0 STUDY AREA

3.1 TUNGABHADRA PROJECT:

The Tungabhadra dam is about 69.25 kms. from Ballary city of Karnataka state . The Tungabhadra dam was completed in 1953. The catchment area of the Tungabhadra is 28,180 sq. km. The total length of the dam is 2.4 km. The water spread area of the reservoir is 378 sq.km, having a maximum width of 15.30 km, near the dam and a fetch of 85.34 km. The storage capacity of the reservoir is 3751 M cu.m.The location of the Tungabhadra reservoir is shown in fig.1

3.2 TUNGABHADRA RIVER

The river Tungabhadra derives its name from two tributaries Tunga and Bhadra both of which take origin in Varahagiri in the Western Ghats of Karnataka state. The two rivers confluence at a village called Kudali near Shimoga. Tungabhadra river flows for a distance of 768 km. before it joins the river Krishna at Sangameswaram in Kurnool District of Andhra Pradesh.

3.3 TUNGABHADRA CATCHMENT

The total catchment area of the Tungabhadra Reservoir is 28,180 sq.km (fig 2). Though it is a perennial river bringing large monsoon flow, the summer flow dwindles down 50 to 100 cumecs only. The soils are mostly red loamy, mixed red and black with patches of lateritic and black soils (fig.3).

The average rainfall in the catchment is 104 cms, the maximum being 432 cms, in the ghats and minimum being 50 cms, in the plains. The river derives major portion of its supplies in its initial course of 206 kms, draining from the western ghats.

The annual river flow varies from 8412 M.cu.m. to 17148 M.cu.m, the average being 11,427 M.cu.m. Though the level of rainfall is quite high, the rate of sedimentation is low because of good forest cover in that region (fig 3). In addition the soils are mainly lateritic, which are not easily susceptible to erosion when there is vegetation cover.

The catchment area can be demarcated into three zones depending on the vegetative growth viz.,(1) The Western ghat belt from Agumbe to Honnali with thick forest and heavy rainfall (2) Thin vegetative cover from Honnali upto Harihar with moderate rainfall and (3) Very thin vegetative growth with bare topped hills beyond Harihar and upto Mallapuram with scanty rainfall.The exposed to different degrees of erosion depending on the rainfall pattern to which they are subjected to (KERS Sedimentation Study

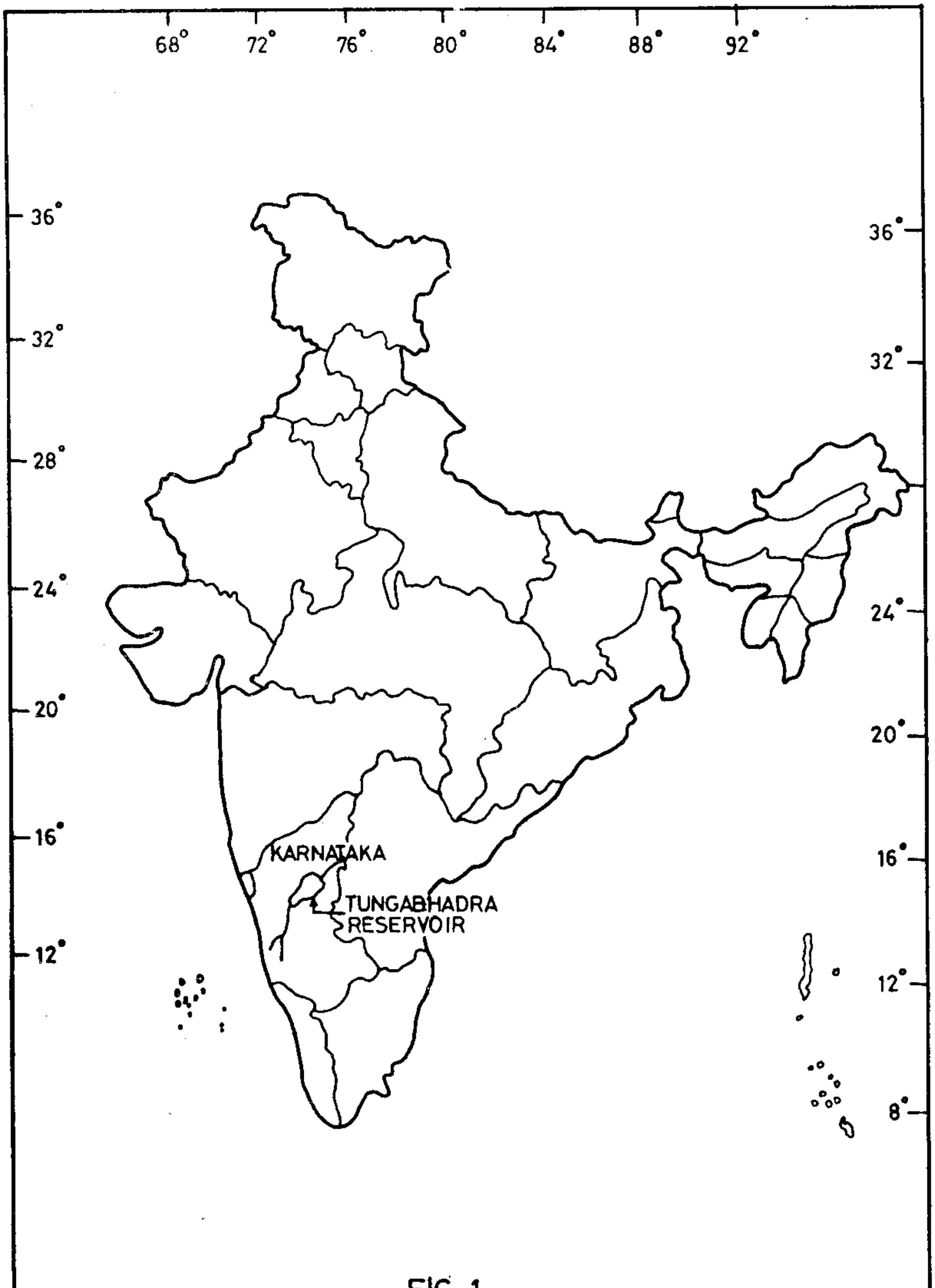


FIG. 1
LOCATION MAP OF TUNGABHADRA RESERVOIR

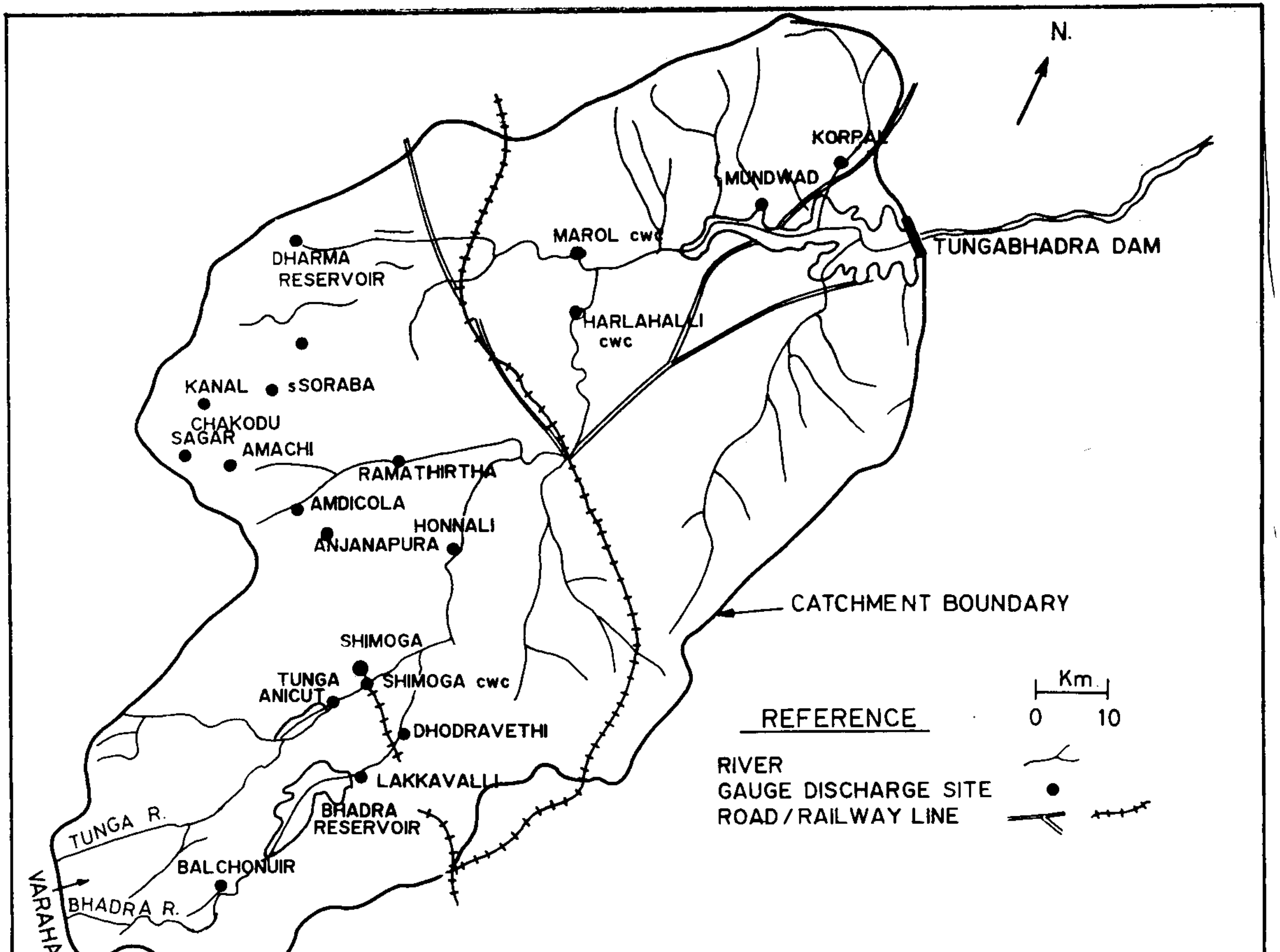


FIG 2 : CATCHMENT MAP FOR TUNGABHADRA RESERVOIR

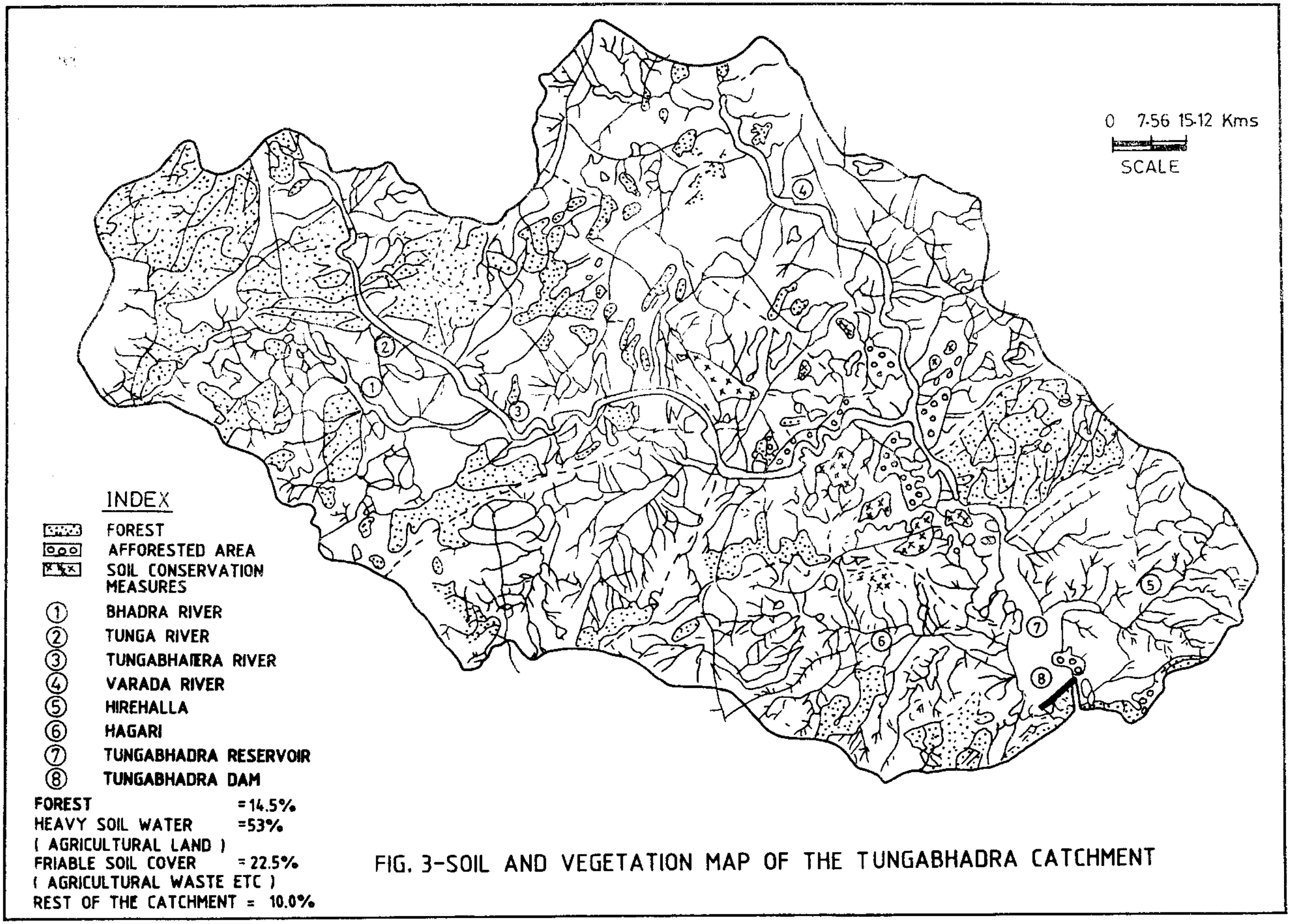


FIG. 3-SOIL AND VEGETATION MAP OF THE TUNGABHADRA CATCHMENT

Report 1985).The erosion intensity will not be same for all nature of soil and vegetation.The value of erodibility factor Fc=0.563.

The land use pattern in the catchment consists of 14.5% under forest (14.5%), cultivation (59%), pastures (9), revenue waste land (12%) and the rest fellow lands (KERS Sedimentation Study Report 1985).

Drainage density of the catchment is 0.44 km/sq.km. The average slope of the catchment is 6%.On the basis of topography, vegetation and the type of soil the value of runoff coefficient is 0.21 (Rao and Mahabaleshwara 1990).

The storage reservoirs existing in the area are (1) Bhadra Reservoir across Bhadra near Lakkavalli (2) Tunga anicut across Tunga near Gajanur (3) Hagari-Bommanahalli reservoir across the river Hagari (4) Bhadra anicut near Bhadravathi (5) Dharma reservoir across the river Varada and (6) Anjanapura reservoir across Kumudvathi. In addition the catchment area is intercepted with a large number of minor tanks. Counting the major and medium reservoirs in the catchment, the intercepted catchment is approximately 6740 sq.kms. and the independent catchment is approximately 21440 sq. kms.

4.0 METHODOLOGY

Both the water level and the water surface area of Tungabhadra reservoir are controlled by Tungabhadra river. The water feature appears in black color in the near infrared, therefore the boundary between water and the other surface features is very clear in Landsat MSS 4.

The satellite images used in this study are given below;

Path	Row	Date of overpass	Satellite Sensor/Band	
144	49	6 March 85	Landsat MSS	1,2,3,4
145	49,50 & 51	28 May 86	Landsat MSS	1,2,3,4
		5 April 87	Landsat MSS	1,2,3,4
		26 Jan. 88	Landsat MSS	1,2,3,4
27	57 & 58	16 Jan. 89	IRS-1A-LISS-II	1,2,3,4
		23 March 89	IRS-1A-LISS-II	1,2,3,4

The black and white multiband and multidate Landsat and IRS-1A-LISS-II images of Tungabhadra reservoir were visually interpreted at different scales. The images of 1:1,000,000 scale were enlarged to 4 X and 6.5 X, 9 X and 17.5X times using large format optical enlarger (LFOE) and DL-2 enlarger to delineate parameters required to assess the sediment concentration within the reservoir.

Water spread area of the reservoir was marked on all Landsat band 4 and IRS-1A-LISS-II band 4 images. The superimposition of the spread area for three years showed distinct changes along the western region of the reservoir (fig.4). The water spread appeared black tone in band 3 and band 4 data while it showed gray tone in band 1 and band 2 data. The band 1 and 2 indicated presence of turbid water.

The reservoir water appears in gray to black tone on all the four bands data, which was delineated on each individual band data and compiled. The turbidity levels were delineated using the visual interpretation key (table 1).

The preliminary analysis of the images provided general idea regarding water spread and sediment concentration within the reservoir. Water spread and sediment distribution pattern were delineated and maps were prepared. An interpretation key (Table 1) was used for qualitative mapping of different concentration levels using all four multispectral bands of Landsat and IRS -1A.

4.1 WATER SPREAD AREA MEASUREMENTS:

Various methods are available for area measurement of water bodies which ultimately can lead to volume estimation. In this study water spread area has been measured by dot grid method, as it was felt that an accurate estimation of reservoir area can be obtained by this method. The reservoir water levels on the day of Landsat and IRS-1A pass and corresponding water spread area are obtained from Tungabhadra Board, Hospet and KERS report (1985) respectively.

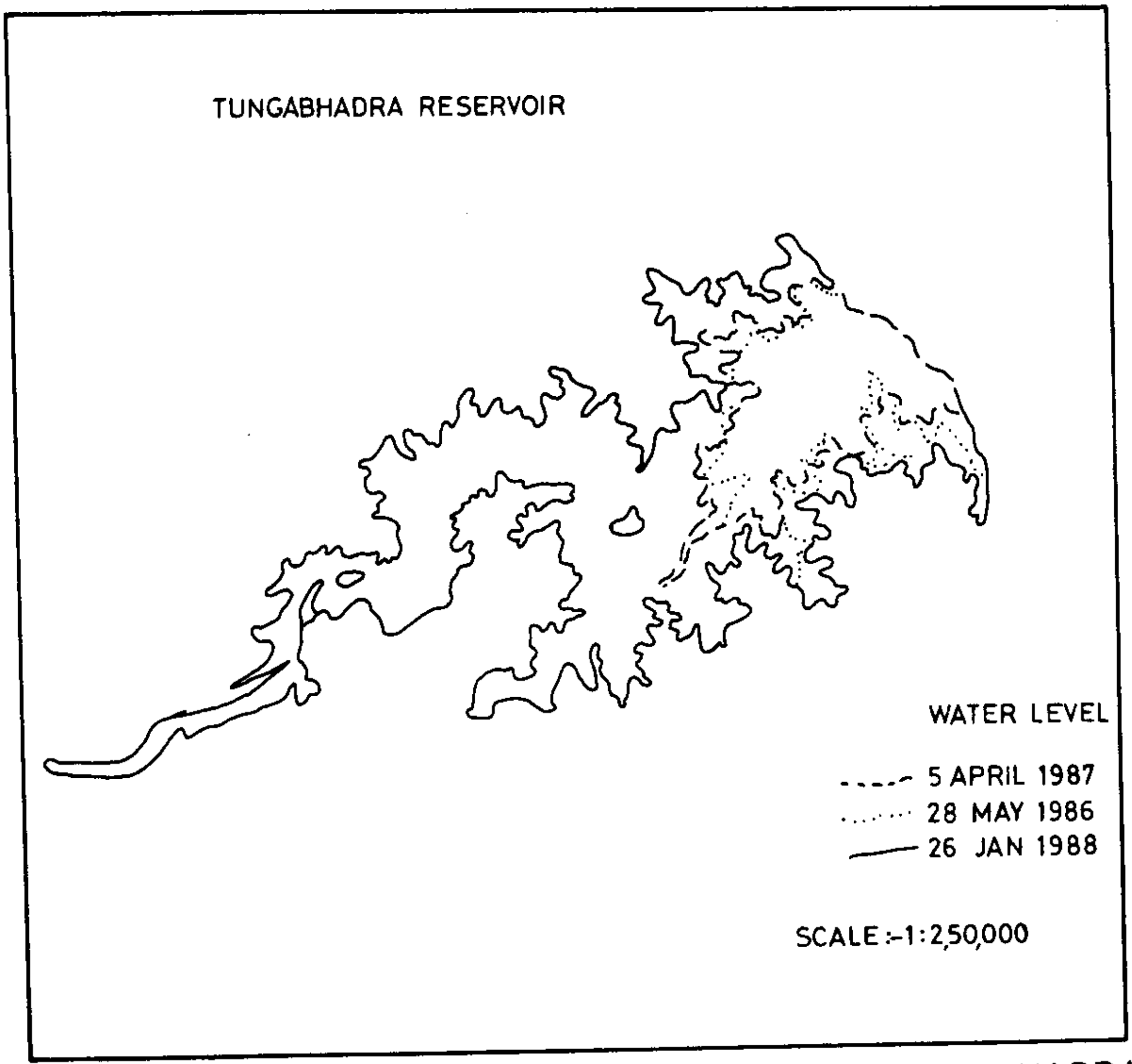


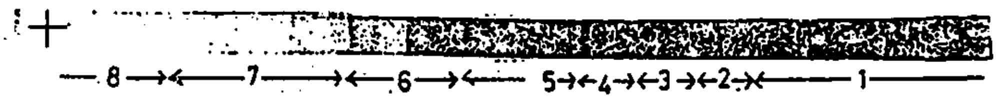
FIG.4-CHANGE IN THE WATER SPREAD OF TUNGABHADRA RESERVOIR PREPARED FROM MULTIDATE LANDSAT IMAGERY

Table : 1

Band-4	Band 5	Band 6	Band 7	Level	Turbidity
DB	DB	DB	DB	I	Nil
B	B	B	B	II	Nil
GB	GB	DB	DB	III	Very low
BG/G	BG/GB	BG/DB	B/DB	IV	
G/BG	BG	DB/BG	DB	V	
G/BG/WG	G/GB	GB	B/GB	VI	
G/WG	G/BG	BG/GB	B/GB	VII	
WG	WG/G	G/GB	GB/BG	VIII	
WG/GW/W	WG	WG/G	G	IX	Very high

Colour Tone

DB	Dark Black	1
B	Black	2
GB	Grayish Black	3
BG	Blakish Gray	4
G	Gray	5
WG	Whitish Gray	6
GW	Grayish White	7
W	White (Bright white)	8



5.0 RESULTS AND DISCUSSIONS

Landsat and IRS-1A imagery offer a complete picture of the area which can be used to study the distribution of suspended sediment in reservoir at that time. The distribution of sedimentation levels within a reservoir depend on the volume of flood water level at the onset of the flood period and the distribution of the water after the flood. The intensity of sedimentation varies from one area to another depending on the prevailing hydrodynamic conditions and sediment load.

The Landsat imagery of pre-monsoon season i.e, 28 May 1986 was used to study the exposed area on the fringe of the reservoir.Its comparison with post monsoon imagery of 26 Jan.1988 provided clues to the deposited sediments. Water spread area of Tungabhadra Reservoir was demarcated using band 4 MSS data. Boundaries between water and land during different seasons were also demarcated.

Different levels of grey tones were marked using bands 1,2 and 4 data for different seasons, which showed concentration of sediment ranging from very high to low.The compilation of these tonal variation produced four levels of grey tones. These levels were indentified by analysing three MSS Landsat bands (1,2 and 4). Fig. 5, shows the suspended sediment distribution pattern in the Tungabhadra reservoir during two seasons January 1988 and May 1986.

Irrespective of season, the sediment concentration is generally high along the fringe and the tail end. The area near the dam, remained relatively free from suspended sediments. The central part of the reservoir is generally covered with intermediate level of sediment concentration. The surface area of water is continuously expanding and contracting with the rise and fall of the water level, and therefore exhibiting a strong correlation.

The January 1988 scene shows maximum water spread area and high concentration of sediments along the tail end. This is due to the arrival of new sediments into the reservoir brought by the flood water through the Tungabhadra river and its tributaries. In all, three concentration levels were identified viz. high, moderate and low.

In the month of May 86 only two concentration levels, namely moderate to high and low were present. Very high and high concentration levels are conspicuous their absence. The settling rate of sediments in water in fall velocity is dependent upon the viscosity of the reservoir water. During summer months, as the water temparature rises, its viscosity is reduced thus increasing the fall velocity and consequently more deposition of suspended sediment takes place. This could be the probable reason for the relatively low concentration level of suspended sediment in the

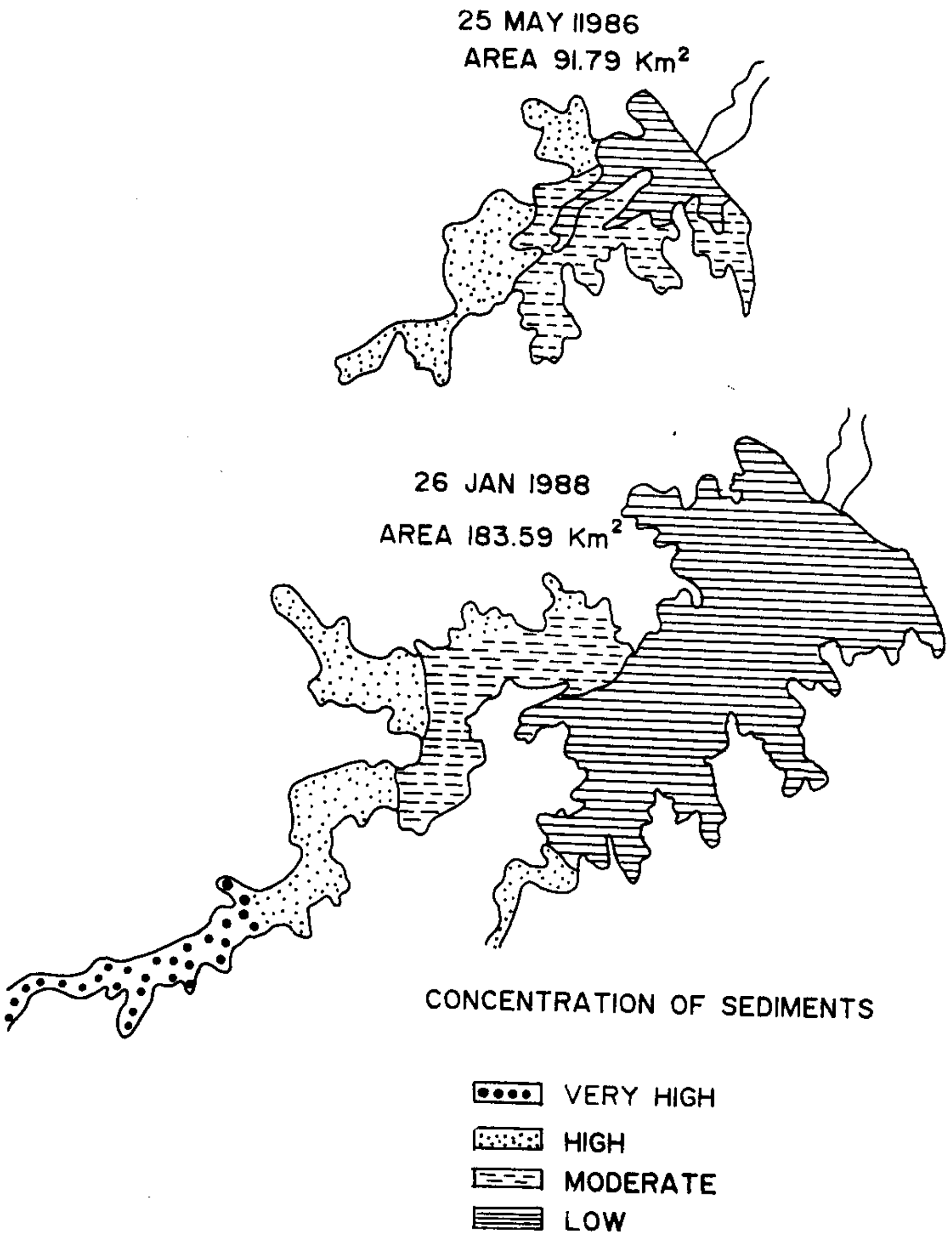


FIG. 5 : SEDIMENT DISTRIBUTION PATTERN IN TUNGABHADRA RESERVOIR

month of May. Out of the four sediment concentration levels identified from Jan. 88 image, three levels observed towards western confluence of Tungabhadra river. Near Infra-red bands (bands 3 and 4) showed dark black to black tone, whereas visible bands (bands 1 and 2) showed peculiar bright tone of the sediment in suspension. This may be due to the presence of the very fine suspended particles, which produced maximum reflection of the incident solar radiation from the water surface in band 1 and 2 data.

5.1 AREA-CAPACITY CURVE:

Reduction in reservoir capacity due to silting can be studied by analysing the area-capacity curve.For studying this curve, series of multidate imageries are required to be analysed.

The water spread area of the reservoir was measured from multidate imageries (March 1985., May 1986.,April 1987 and Jan. 1988) by dot grid method. Water levels of the reservoir corresponding to date of imageries were noted down from the Tungabhadra Board and KERS Sedimentation Survey Report 1985. Volume of the reservoir between two subsequent dates are calculated using well known Prismoidal formula.

$$V = \frac{(A_1 + A_2 + \sqrt{A_1 A_2})}{3} H$$

where

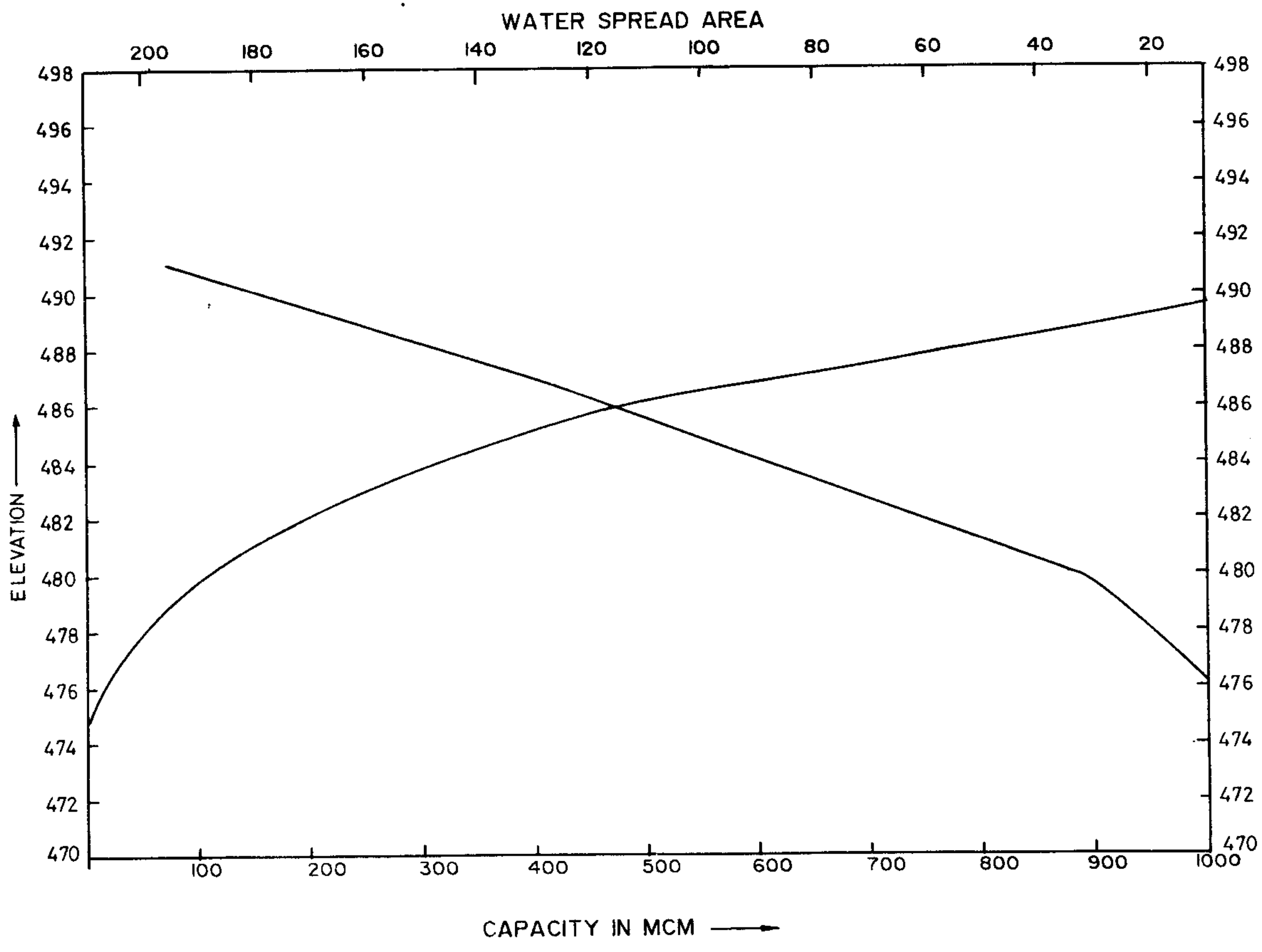
S = Reservoir storage

A_1 = Water surface area level 1

A_2 = Water surface area level 2

H = Difference in height between level 1 level 2

The cumulative volume was calculated taking the volume of the reservoir water from the area capacity table prepared by the reservoir authorities. A new area capacity curve (Fig.6) was drawn, and compared with that obtained by conventional method.The volumes for each reservoir level is given in table 2. The area capacity curve obtained from the study has been found to be in close agreement with that obtained from hydrographic survey KERS 1985).



TUNGABHADRA RESERVOIR AREA CAPACITY CURVE PREPARED
FROM MULTIDATE LANDSAT IMAGERY

FIG. 6

Table 2

Tungabhadra reservoir: Area capacity (Using Landsat imageries)

Reservoir level (m)	Area (Water spread) (Sq.m)	TBP W.S.P	Capacity M.cu.m.
480.10	32.5	30.77	88.53
480.20	32.9	31.45	91.01
481.00	37.0	37.46	122.48
486.50	124.3	112.34	511.07
486.60	125.2	113.71	520.57
489.40	175.0	165.75	899.86
492.10	237.0	223.44	1432.73

* data taken from Tungabhadra reservoir sedimentation studies report 1985.

5.2 RELATIONSHIP BETWEEN THE WATER LEVEL, WATER SURFACE AREA AND CAPACITY

As the water surface area is expands and contracts with the rise and fall of the water level, a correlation between the two was established. The coefficient of determination for Tungabhadra reservoir water level and water spread area and corresponding capacity is 0.98 and 0.93 respectively. The relationships between reservoir water level,water spread area and capacity are shown in fig 7 and fig.8 respectively.

5.3 QUANTITATIVE ASSESSMENT OF SEDIMENT DEPOSIT

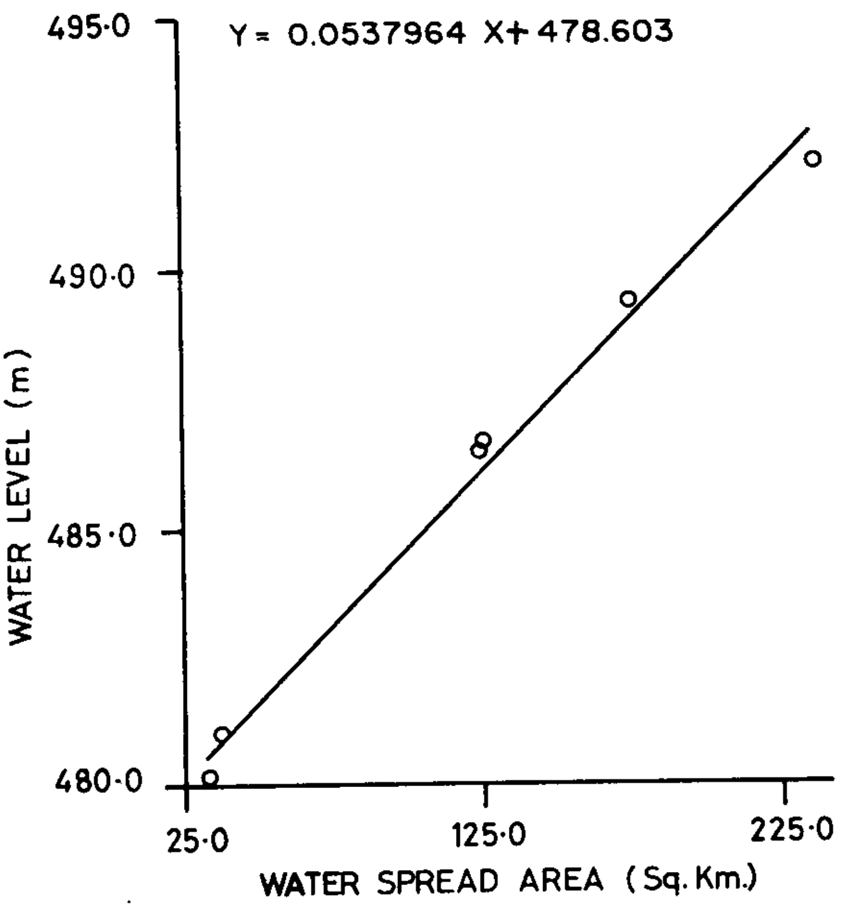
IRS- 1A- LISS-II imageries of Jan 1989 and March 1989 scale were used for measuring the water spread area by dot grid method. The water level and capacity corresponding to this area was taken from KERS Sedimentation Report (1985).

Date	Water spread area in sq.km	Capacity M.cu.m	Water level (m).
16 January 1989	237.00	1432.73	492.10
23 March 1989	37.00	122.48	481.00

Accumulated sediment deposits between January 1989 and March 1989 water level were calculated based on KERS Sedimentation Report (1985). The observed quantity of sediment deposits is 312.34 M.cu.m.

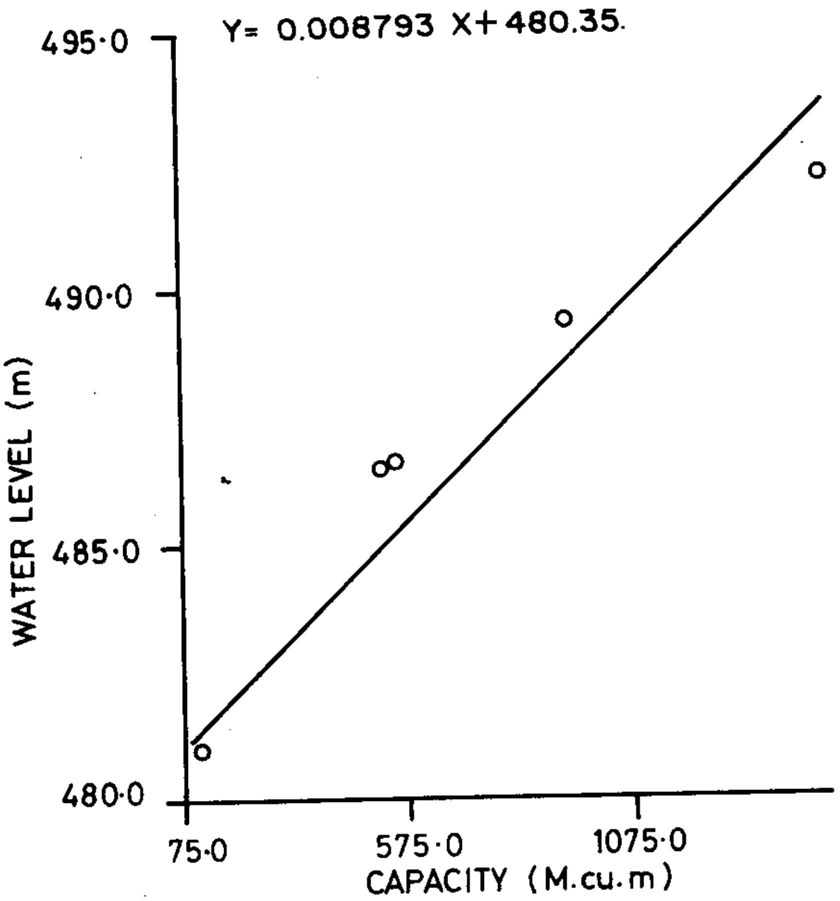
The minimum and maximum reservoir levels for 1984-1985 are 477.05 and 497.738 meters respectively. Table 3 indicates the quantity of silt deposited at different contour intervals and the percentage of siltation in capacity between contours. Fig 9, exhibits a relationship between the percentage of silt deposits V/s reservoir elevation.

The computed average sedimentation rate of 6 ha.m/100 sq.km/ year obtained for this study compares well with that of observed rate of siltation of 6.48 ha.m/100 sq.km/year.



Y= 0.0537964 X+ 478.603
495·0
490·0
485·0
480·0
WATER LEVEL (m)
25·0
125·0
225·0
WATER SPREAD AREA (Sq. Km.)

FIG. 7



Y= 0.008793 X+ 480.35.
495·0
490·0
485·0
480·0
WATER LEVEL (m)
75·0
575·0
1075·0
CAPACITY (M.cu.m)

FIG. 8

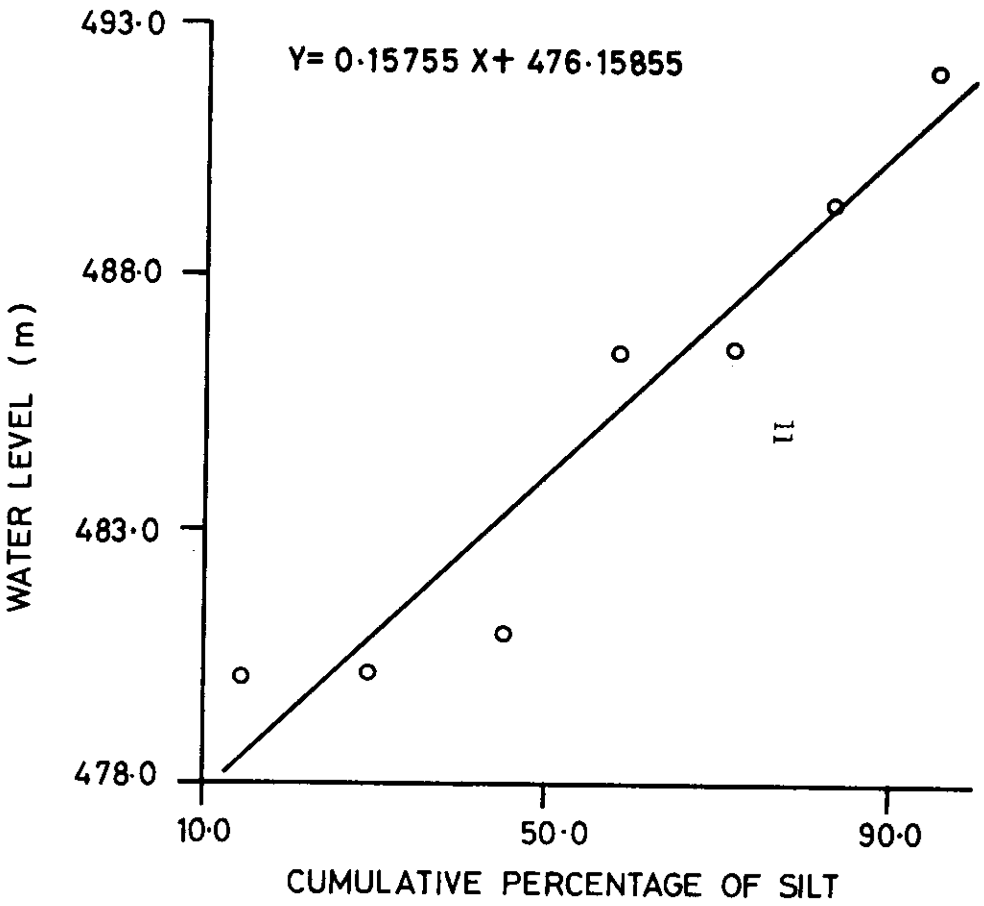

Y= 0·15755 X+ 476·15855
493·0
488·0
483·0
478·0
WATER LEVEL (m)
10·0
50·0
90·0
CUMULATIVE PERCENTAGE OF SILT

FIG. 9

Table:3 Percentage of silt deposit between contours

Water Level in meters	Cumulative % of silt upto each contour	Percentage of silt between contour	Water capacity (M.cum.)
480.1	14.632	14.632	88.5277
480.2	29.367	14.735	91.0108
481.0	45.245	15.878	122.4794
486.5	58.595	13.350	511.0743
486.6	71.839	13.244	520.5689
489.4	83.469	11.630	899.8621
492.1	95.377	11.908	1432.7318

4.623% silt upto 497.738 meters

6.0 CONCLUSIONS

Multidate Landsat images are extremely useful in mapping the concentration of sediment load and other water quality parameters in the reservoir. However, Landsat images have some limitations. The water surface area and capacity of Tungabhadra reservoir were analysed using Landsat MSS and IRS- 1A- LISS- II imageries at 7 elevation levels between 480.10 to 492.10 m.msl. The main conclusions drawn from this study are as follows.

(1) Landsat bands 1 and 2 give better information about the distribution of suspended sediment in the water column, and near infra-red bands 3 and 4 for land-water interface, however analysis of all the four bands together is essential for the qualitative mapping of sediment distribution pattern.

(2) Multidate and multiband Landsat MSS and IRS images provide invaluable synoptic and timely information regarding the water spread and sediment distribution pattern in the water body, which help in the selection of the sampling points for quantitative estimation of the sediment in the reservoir.

(3) In the Tungabhadra reservoir high concentration of sediment is generally observed at the western confluence of the Tungabhadra river.On the basis of the degree of sediment concentration, the reservoir could be divided into three major concentration zones viz., very high at the river confluence, moderately at the fringes and low at the dam site.

(4) High resolution satellite images viz., Landsat TM, SPOT and IRS-1A - LISS-II would be more useful for the quantitative assessment of suspended load. Further hydrodynamic models can be coupled with digital satellite data for monitoring the sedimentation by correlating reflectance values with sedimentation rate.

(5) Area capacity curve can be prepared from satellite images. The same curve was generated for the study, which is found to be in close agreement with that obtained from hydrographic survey.

(6) The average sedimentation rate of 6 ha.m/100 sq.km/year obtained from this study compares well with that of observed rate of siltation of 6.48 ha.m/100 sq.km/year.

REFERENCES

1. Choubey V.K (1988). Remote Sensing for Sedimentation studies in reservoir.TR-57 NIH Roorkee

2. Choubey V.K.(1990). Modelling sediment and dissolved load of the Tawa reservoir and river (M.P) by Remote Sensing techniques Ph.D thesis JNU New Delhi.

3. Khorram, S. and H.M. Cheshire (1985). Remote Sensing of Water quality in the Neuse River estuary North Corolina. Photogrammetric Eng. and Remote Sensing, LI (3) pp 329-342.

4. Muley, M.V., E. Amminedu., R. Uday., M. Chakraborty and V.Tamilarasan (1986). Water quality mapping in lakes and reservoirs using multitemporal Landsat imagery. IRS-UP/SAC WQM/SM/03/86. SAC Ahmedabad.

5. Rao H.S.S and Mahabaleshwara (1990) prediction of rate of sedimentation of Tungabhadra reservoir. Proceedings of Int.Sym.on sedimentation and resource conservation,pp 12-20.

6. Ritchie, J.C., F.R. Schiebe and J.R. McHenry (1976). Remote Sensing of suspended sediment in surface waters. Photogrammetric Eng. and Remote Sensing,42 (12) pp 1539-1545.

7. Ritchie J.C. and C.M Cooper (1988) suspended sediment concentration estimated from Landsat MSS data. Int. J. Remote Sensing 9(3): 379-387.

8. Tungabhadra reservoir sedimentation studies report (1985).

9. Weishlatt E.A et al (1973), classification of turbidity level in Texas Marine Coastal Zone. Conference of proceedings of machine processing of remotely sensed data LARS, Purdue University Oct. 1973, pp 3A-42 to 3A-59.

10. Yarger, H.L., J.R.McCauly., G.W.James., L.M. Magnuson and G. Richard (1974). Water turbidity detection using ERTS-1 imagery. Proceedings of 3rd ERTS-1 symposium Washington DC pp 651-600.

DIRECTOR	SATISH CHANDRA
HEAD	K.S.RAMASHASTRI
STUDY GROUP	V.K.CHOUBEY