TEMPORAL ANALYSIS OF AREA-CAPACITY CURVE FOR HIRAKUD RESERVOIR

SUBMITTED BY SONAM TOBGAY

110CE0641

UNDER THE SUPERVISION OF

DR. RAMAKAR JHA

Department of civil engineering

National institute of technology, Rourkela

Rourkela – 769008

CERTIFICATE

This is to certify that the project entitled, "**THE TEMPORAL ANALYSIS OF AREA CAPACITY CURVE OF HIRAKUD RESERVOIR**" submitted by **SONAM TOBGAY** in partial fulfillments for the requirements for the award of Bachelor of Technology Degree in Civil Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any Degree or Diploma.

Date:

Dr. Ramakar Jha

Department of Civil Engineering

National Institute of Technology

Rourkela – 769008, Odisha

ACKNOWLEDGEMENT

I would like to express my deepest appreciation to all those who provided me the possibility to complete this report. A special gratitude I give to my supervisor, Dr. R.Jha, who gave his full effort in guiding me in achieving the goal and whose contribution in stimulating suggestions and encouragement and the help he rendered, helped me to coordinate my project.

Furthermore I would also like to acknowledge with much appreciation the crucial role of Dr. N.Roy, HOD, Department of Civil Engineering, for providing all the facilities during the course of my tenure.

I would like to acknowledge the support of all the faculty and friends of Civil Engineering Department, NIT Rourkela.

I thank to the support, encouragement and good wishes of my parents and family members, without which I would not have been able to complete my thesis.

ABSTRACT

Humans has found various ways to use water and construction of dam and reservoir for the storage being one of them. Water is stored to be used for purpose of drinking, irrigation, power generation, etc. The reservoir sedimentation plays a vital role in the determining the storage capacity in any reservoir thereby directly influencing the water available for irrigation, power generation. The rate of sedimentation of any reservoir or dam is defined by silt index.

One of the most important physical characteristics of dams and their reservoirs are area-capacity curves. Area-capacity curves are important for defining the storage capacity of the reservoir, thereby can be used in reservoir operation, reservoir flood routing, determination of capacity and water spread corresponding to each elevation

This study deals with analyzing the area capacity curve using ILWIS 3.3 software to find the area and cone formula to find the corresponding capacity or volume. Then thorough analysis of reduction in capacity from the time of construction to year 2012. It also deals with changes in water spread area for different reservoir for different year and the results obtained are compared for different years and RLs to the original data at the time when it was first functioned.

The interest for studying Hirakud dam comes from it being the longest man-made dam in the world which extends 16 miles (26 Km) in length which was constructed in between 1948-1957 with estimated cost of 1.01 billion.

CONTENTS AND LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Dams are structural barriers that control the flow of water in rivers and streams, they are designed to do the following two functions: 1) to store water to compensate changes in river discharge, 2) increase the hydraulic difference between upstream of the dam and downstream of the river.

Area-capacity curves are important for defining the storage capacity of the reservoir, thereby can be used in reservoir operation, reservoir flood routing, determination of capacity and water spread corresponding to each elevation.

Reservoirs of large and medium size were built under various plan periods and other is under construction. These reservoir need to meet various requirements of the community, under certain monsoon rainfall condition non-uniform distribution of the precipitation, after the dam is built the silt-laden water flows into the reservoir causing siltation in both Live and dead storage of the reservoir, thus utilizable water storage and benefits from the reservoir are reduced. Life of the reservoir is reduced when the rate of sedimentation is higher than the design rate. The capacity of the reservoir is affected by various components like change the amount of rainfall, temperature, as with time the capacity decreases and when it comes to water spread area they solely depend on water level, rainfall and runoff.

Water spread area estimation is one of the most easily deniable features on the satellite data due to high contrast between land and the water boundaries in Near Infrared Region (NIR). Water absorbs almost entire incident energy depending on nature and status of the water body while land features absorbs less depending on cover type, roughness, composition, etc.

The area capacity curve is generated by first finding the water spread area using ILWIS 3.3 software, satellite data of know reservoir level was taken and the outline of water was drawn to find out the water spread area at that level. Finding water-spread area its capacity was found out using cone formula which is stated in next chapters.

Being familiar: Definitions

Full Reservoir Level: Denoted by FRL this level corresponds to the storage which includes both inactive and active storages and also the flood storage, it is the highest reservoir level that can be maintained without spillway discharge.

Minimum Drawdown Level (MDDL): It is the level below which the water from reservoir will not be drawn down to maintain a minimum head required in power projects.

Maximum Water Level (MWL): This the water level that likely to be attained during the passage of the design flood. This level is also called as the highest reservoir level or the highest flood level**.**

Live storage: it is volume of water actually available at any time between the Dead Storage Level and the lower of the actual water level and Full Reservoir Level.

Dead storage: It is the total storage below the invert level of the lowest discharge outlet from the reservoir. It may be available to contain sedimentation, provided the sediment does not adversely affect the lowest discharge.

OBJECTIVES

- **Historical background and the dam design survey –**
  The full history of the Hirakud reservoir in the sense, the year of construction, type of construction, levels and capacities at the time construction, etc. If the record is available on the features of Hirakud dam design then it is analyzed

- **Analysis of reduction in the capacity –**
  The data on capacity for the various years are collected from different journals, websites, and provided from the Hirakud reservoir department. They are compared, analyzed and their relations are shown in the form of tables, charts, graphs, etc.

- **The temporal analysis of area capacity curve**
  The relationship is derived between water spread area and the capacity of the reservoir and their change with passing time

- **Comparison of the results with historical data**
  The water spread area and the capacity found out from this study is compared with the historical data obtained from various hyrdographical and remote sensing surveys. The comparison are shown in the form of tables, graphs, charts, etc.

CHAPTER 2

LITERATURE REVIEW

Rathore *et al*.(2006) studied assessment of sedimentation in Hirakud reservoir using remote sensing technique

Reservoir's original utilizable and gross volumes were 5818 and 8136 M m^3, respectively. Minimum draw down level and full reservoir level (FRL) for reservoir were 179.83 m and 192.02 m. Linear Imaging Self Scanning (LISS)-111 data covering elevation range between 180.68 and 191.89 m, were used to determine the water-spread area. Revised live storage capacity was 4842 M m^3. Silt index for the live storage area was 2.623 ha m (100 km^2 per year (0.376 % of live storage or 21.9 M m^3 per year). Total live storage lost in sedimentation was 984 M m^3 (16.90% of live storage).

Reservoir's original utilizable and gross volumes were 5818 M m^3 and 8136 M m^3 respectively. Design silt index was 2.5 ha m (100 km^2 year)$^{-1}$

Total live storage loss between1957 and 2001 was 984 M m^3. In percentage terms, total and yearly losses in live storage were 16.9 % and 0.376 % of live storage volume respectively. Silt index for live storage zone was 2.623 ha m per 100 km^2 per year which was higher than design silt index.

Muhaerjee *et al*. and Josh (2007) studied to evaluate the changes in water spread area and capacity loss, five satellite overpass data were used (October 15th 1988, December 20th 1988, February 24th 1989, March 18th 1989 & May 1st 1989.)

- ✓ The live and gross storage capacities of the reservoir were estimated to be 6151.30 M.Cu.m during 1989, since the dead storage has been estimated as zero.
- ✓ The capacity loss of 1953.70 M.Cu.m. (24.10 percent) from 1957 to 1989.
- ✓ Annual rate of siltation is found to be 61.05 M.Cu.m, since impoundment of reservoir in 1957 to 1989.

Report of high level technique committee (HTLC) to study various aspects of water usage for Hirakud reservoir (2007) –

Benefits of Hirakud dam

Pre-construction period- 8 floods in 10 years

Post-construction period – 3.30 floods in 10 years

<u>Flood control</u>

The construction of dam has reduced the occurring of flood from 8 floods in 10 years to 3.3 floods in 10 year after construction

<u>Irrigation</u>

The reservoir storage has been used extensively for irrigation and, the potential already developed and utilized is substantially more than the provisions made in the project report. The quantum of water supplied is seen to be steadily on the rise for the same level of irrigated area indicating reduction in efficiency of water use

Water released from the dam toe power house flows down to provide water for irrigation to 1,36,000 ha in Delta Stage –II and 1,67,000 ha of Delta Stage –I.

Power generation

Power is generated at the dam toe power house is 272.87 MW.

Reported by Priyabrata, Sucharita and Pranab (2010) -Odisha State Center of the Forum, studied the first release of flood water from Hirakud Reservoir .

- ✓ Flood control demands empty storage space to absorb the flood for regulated release. As per the provision, water level of the reservoir should remain at 590 feet in the month of July.

Pranab Choudhury, Jinda Sandbhor, Priyabrata Satapathy(2010) made a report on Hirakud Dam, Odisha State Resource Centre, Forum for Policy Dialogue on Water Conflicts in India

- ✓ the gross storage in year 2000 was decreased to 5,896 M cu.m from 8,141 M cu. M in 1957 (originally)

- ✓ The Hirakud dam project was designed as a multipurpose project, with provisions to supply water for irrigation, power generation, drinking water, navigation and fishery but there was no industrial water allocation in the initial plan, though a handful of industrial units were drawing water from the reservoir.

- ✓ However since 1991 there has been a lot of disputes between the dam officials and farmers over the provision of providing water to the industries as farmers are said to be falling short of irrigation water because of water being supplied to the industries and factories.

CHAPTER 3

STUDY AREA

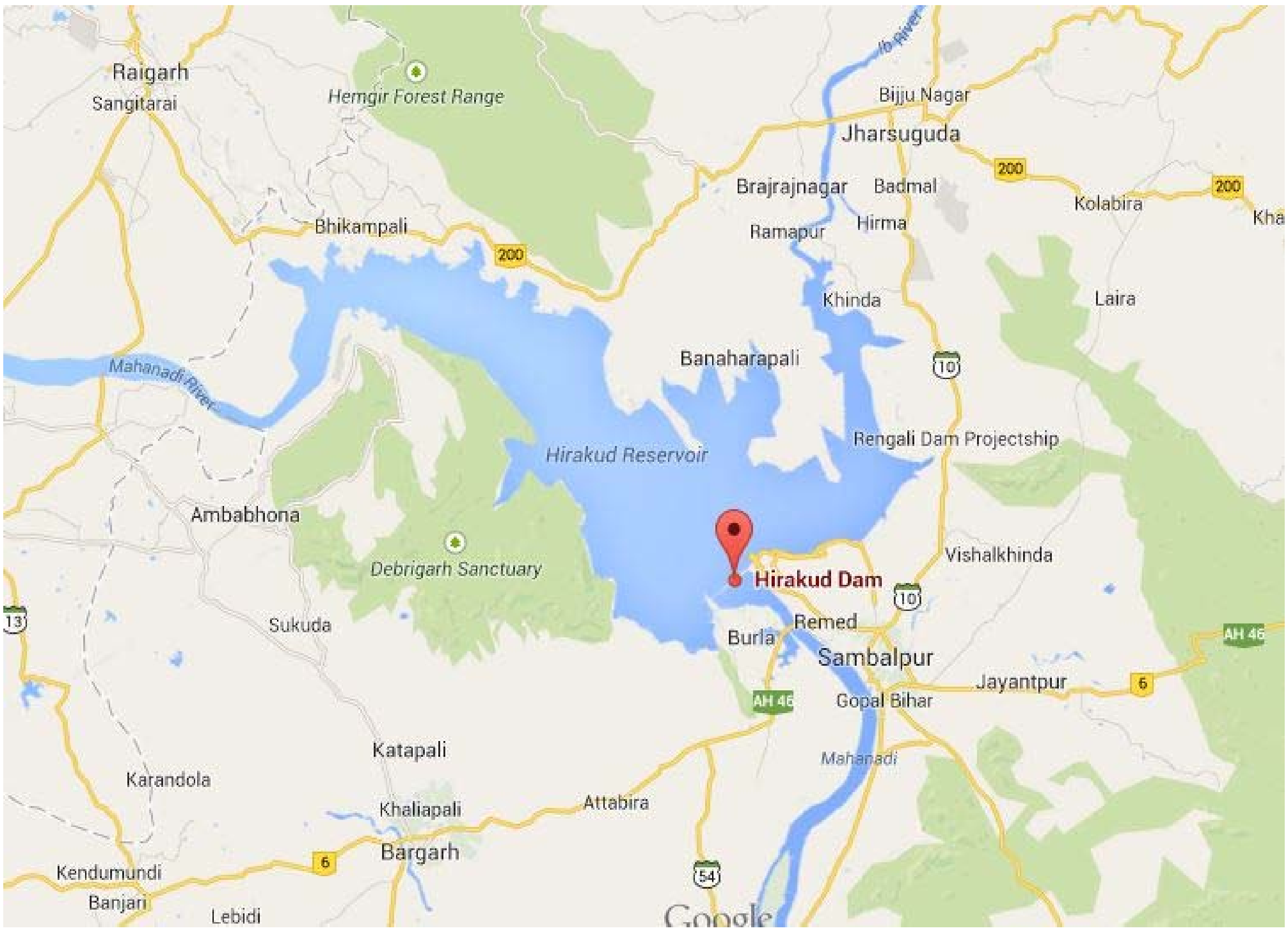


Figure 1 : showing the location of Hirakud reservoir

Location

The Hirakud dam It located at the cordinates of 21.57^{o} N and 83.87^{o} E on globe. It is constructed across Mahanadi and is located 15 km from Sambalpur in Orissa, India. The project is a multipurpose project with objectives namely irrigation, power generation and flood control. Powerhouses are located at Burla and Chiplima. The reservoir is located in Jharsuguda, Bargarh and Sambalpur districts of Orissa. Mahanadi delta in Puri and Cuttack districts of Orissa is protected from floods by the project.

Catchment characteristics

89.90% of the catchment upto the dam is in Chhattisgarh which is about 74,970 Km^2 Madhya pradesh makes just 0.1% and 0.3% is located in Maharastra while Bihar and Orrisa makes up 0.8% and 8.8% of the 83400 Km^2 catchment area. Whereas orrisa makes up 46.3% and majority Chhattisgarh makes 52.9% of total 141600 Km^2 catchment area.

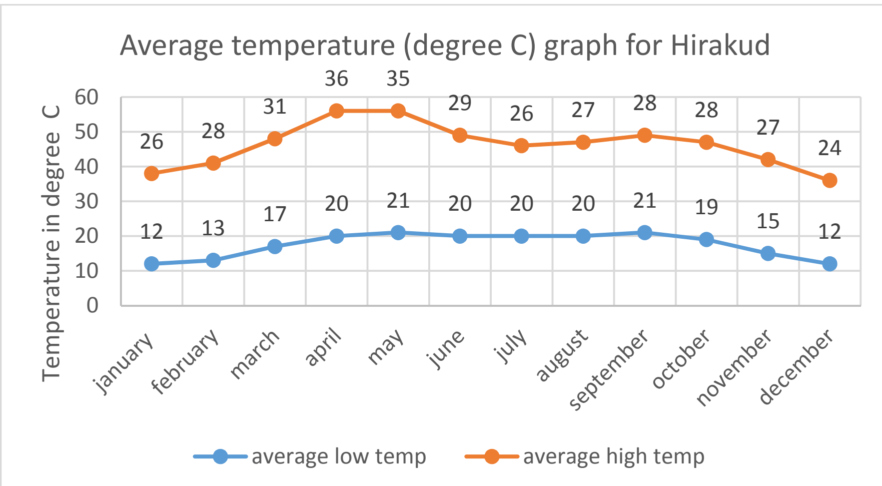
Table 1: showing distribution of catchment area of Hirakud reservoir in different states

State	Area in sq. km and % of total			
	Catchment up to dam		Total catchment	
Chhattisgarh	74,970	- 89.9	74,970	52.9
Madhya Pradesh	130	- 0.1	130	0.1
Maharashtra	250	- 0.3	250	0.2
Bihar	650	- 0.8	650	0.5
Orissa	7,400	- 8.8	65,600	46.3
Total	83400	- 100.0	141600	100.0

Temperature

The average highest monthly temperature is observed at the month of April with 36°C while the average lowest was observed during December and January months (winter months). The highest temperature may just go up to 45° C in summer and might enter negative temperature during winter season.

Figure 2: showing average monthly temperature for Hirakud

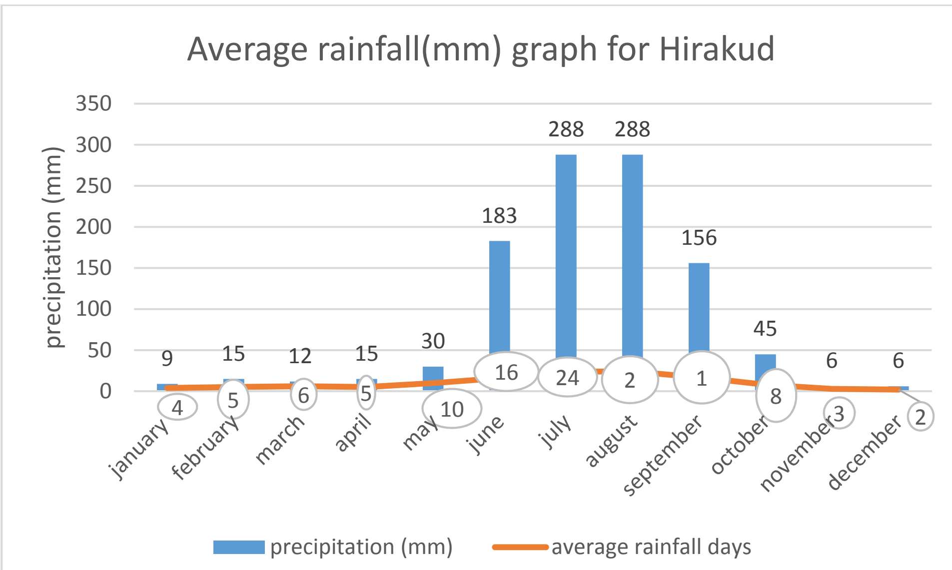


Rainfall

The highest rainfall has been observed in the month of July and August with a rainfall depth of 288 mm with 24 days in a month rainfall which is particularly high. The lowest is observed in December and November with 2 and 3 rainfall days respectively.

.

Figure 3: showing average rainfall in months of the year, the values inside circle showing the number of days of rainfall in a month



CHAPTER 4

HISTORICAL BACKGROUND OF HIRAKUD RESERVOIR

Before the devastating floods of 1937, Sir M.Visveswaraya proposed a detailed investigation for storage reservoirs in the Mahanadi basin to tackle the problem of floods in the Mahanadi delta. In 1945, under the chairmanship of Dr. B. R. Ambedkar, Member of Labour, it was decided to invest in the potential benefits of controlling the Mahanadi for multi-purpose use. The Central Waterways, Irrigation and Navigation Commission took up the work and proposed a detailed investigation for storage reservoirs in the Mahanadi basin to tackle the problem of floods in the Mahanadi delta.

On 15th March 1946, Sir Howthrone Lewis laid the foundation for the construction of the longest man-made dam in the world which extends 26 Km in length. It was constructed in between 1948 and 1957with estimated cost of 1.01 billion which was completed in 1953, formally inaugurated by PM Jawaharlal Nehru on 13th January 1957.The quantity of earthwork in the dam was estimated to be 18,100,000 m^3 and concrete quantity of 1,070,000 m^3 and the area lost in the construction of the dam was about 596.36 Km^2. Nearly 150,000 people were affected by the Hirakud project and nearly 22,000 families were displaced by the dam project.

The composite dam was initially designed at 60.96 m with main stream dam length of 4.8 Km and 25.8 Km entire. The capacity during the time of inauguration was 5896 M m^3 with top dam level of RL 195.680 m, full reservoir level RL 192.024 m and dead storage level RL 179.83 meter, the catchment area of the reservoir is 83,400 Km^3 and the reservoir formed an artificial lake of 743 Km^2.

The main purpose of the dam was to protect the flood in Mahanadi deltas and it protects about 9500 Km^2 of delta area, the secondary purpose being the irrigation it irrigates 1,08,385 Hectares of Rabi crops and 1,59,106 Hectares of Kharif crops . It also generates power of 307.5 MW

Technical details

- Total length of dam Total length of the dam=25.8 Km
- Length of main section of the dam=4.8 Km
- Artificial lake or water-spread area=743 Km^2
- Total area irrigated both Rabi and Kharif crops=235477 Hectares
- Area lost in construction of dam= 596.36 km^2
- Water-spread area at dead storage level =274 km^2
- Power generation =307.5 MW
- Cost of construction of the dam=1000.2 million Rupees(at the time of construction)
- Top dam level= RL 195.680 meters
- Full reservoir level or maximum water level = RL 192.024 meters
- Dead storage level= RL 179.830 meter
- Total quantity of earth work in Dam = 18,100,000 cubic meters
- Total quantity of concrete used for construction – 1,070,000 m^3
- Catchment area=834400 km^2
- Height of the dam at the time of construction= 60.96 meters (200ft)
- Original gross storage = 8136 M. m^3
- Dead storage = 2318 M. m^3

Spillway

Spillway capacity = 42450 m^3

Crest level= RL 185.928 meters

Size of sluices= 3.658 m X 6.20 m

Number of sluices = 60 (40 on left and 24 on the right)

Sill level of sluices = RL 155.448 meters

Number of crest gates = 34 (21 on left and 13 m on the right)

Size of crest gate= 15.54 m X 6.10 m

Structure

The Hirakud dam is a composite structure of earth,concrete and masonry, 10 km north of sambalpu, it is the longest major earthern dam in Asia, measuring 25.8 km including dykes and strands across the river. The main dam of 4.8 km spans between two hills: 1) Lamdungri on the left and 2) Chandili Dunguri on the right. There are two observation tower on the dam one at each side. “Gandi Minar” and Nehru Minar” both the observation tower gives breathtaking views of the lake.

Purpose

- ✓ The Hirakud dam was mainly constructed to control the floods in the delta region of Mahanadi, it provides flood protection to 9500 km^2 of delta area in the district of Cuttak and Puri.

- ✓ Irrigation – the project provides water for irrigation of approximately 1,566 km^2 of Kharif crops and 1,084 km^2 of Rabi irrigation in the districts of Sambulpur, Bargarh, Bolangri and sanbarnpur. The water released by the power plant again irrigates 4360 km^2 of crops in Mahanadi delta.

- ✓ Power Generation-

  Generates total of 307.5 MW power , power house-1 produces 259.5 MW of power (3 x 37.5 MW kalpan turbine and 2 x 24 MW Francis turbine) while power house-2 produces the rest .

- ✓ Wildlife – The dam with the channel provides an ideal environment for the wildlife sanctuary. Several species of migratory birds visit the reservoir during the winter and nearly 20-25 species of birds are seen here and common among them are common Pochard, Red-crested pochard, great crested grebe.

CHAPTER 5

ANALYSIS OF CHANGE IN WATER SPREAD AREA WITH TIME

Methodology

Water is one of the most easily delineable features on the satellite data due to high contrast between land and water boundaries in Near Infrared Band (NIR), where water absorbs almost all entire incident energy depending on nature and status of water body while land feature absorbs less depending on cover type, roughness, composition etc.

After analyzing the histogram of the ratioed (RED/NIR) image the ranges for land/water boundary demarcation shall be identified. The ratioed image shall then be threshold by roaming the cursor on FCC image with numeric display of ratioed image on. These values containing all water pixels were verified by consulting standard FCC to change the threshold value. But in most of the cases criterion of thresholding ratioed image has not yielded satisfactory results in identifying the correct water pixels due to shallow depth of water at some of the locations along the periphery and the tail portion of the reservoir. Hence actual water pixels in that case were estimated by thresholding the ratioed (GREEN/NIR) image.

Finally, the isolated water patches, which do not have any hydraulic connectivity with contiguous water area

Table 2: Live storage volume and water spread area for year 1957, 1986, 1995 and 2001

	1957(original)	1986 (hydrographic)	1995(remote sensing based)	2001 (remote sensing based)
Live storage in M m^3	5826	5106	4901	4842
Water spread area at MDDL(179.83m)in km^2	278	229	170	175
Water spread area at FRL (192.02 m) in km^2	727	619	691	676

Fig 4: Decreasing trend in live storage of Hirakud reservoir

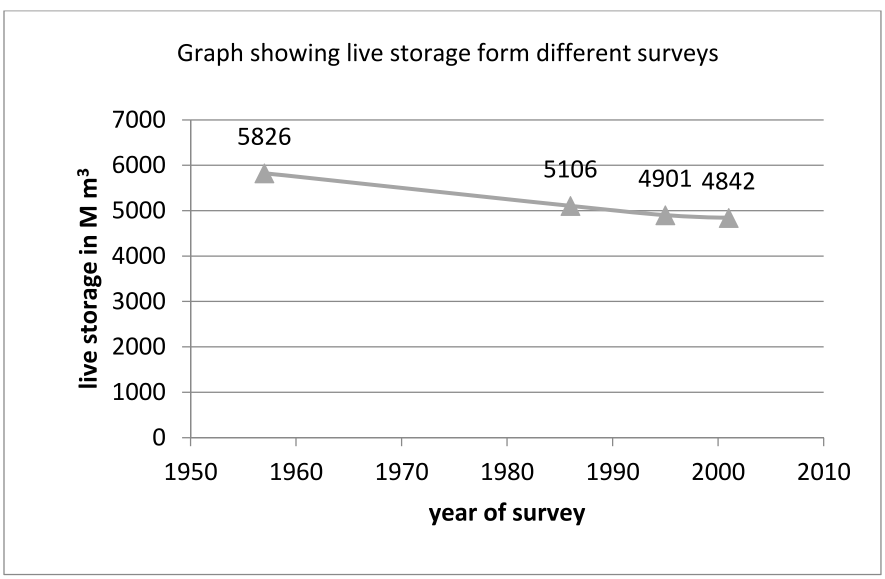
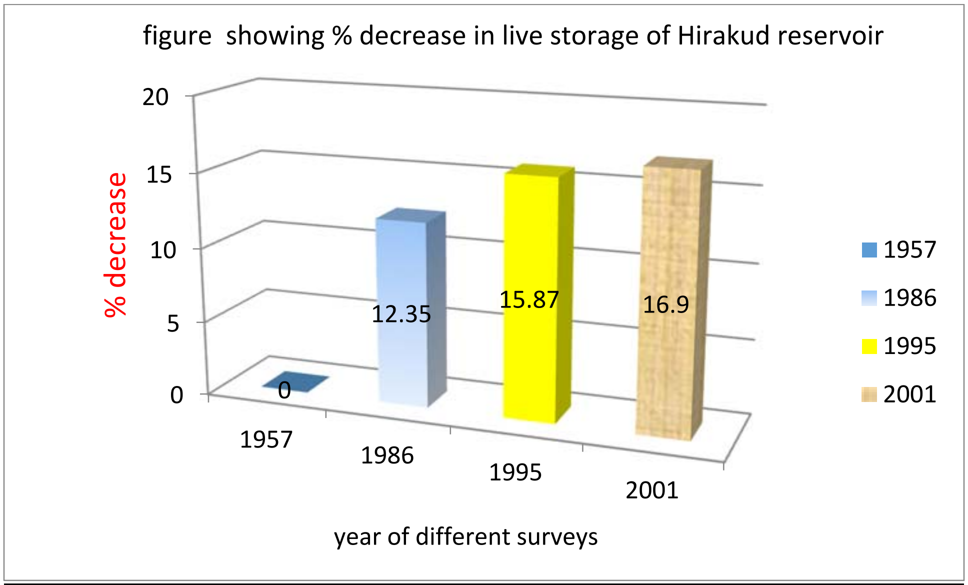


Figure 5: showing percentage decrease in live storage of Hirakud reservoir



Live storage available for the intended purpose between Full Supply Level and the Invert Level of the lowest discharge outlet. This may also be termed as the volume of water actually available at any time between the Dead Storage Level and the lower of the actual water level and Full Reservoir Level. These data were obtained from the study carried out by D.S. Rathore et.al, Figure 5 shows how live storage is decreasing with time. The live storage at the time of construction or at the time when it first functioned was 5826 M m^3, in 1986 hydrographical survey the live storage was found out to be 5106 M m^3 showing 720 M m^3 decrease in live storage over 29 years. There is decrease in live storage because of sedimentation

Figure 5 shows the percentage change in live storage or percentage decrease in live storage for different hydrographical and remote sensing surveys. The live storage was decreased by 12.35%, 15.7% and 16.9% for the year 1986, 1995 and 2001 respectively. It's obvious that the percentage decrease in 2001 was the highest because as the age of the reservoir increases the deposition of silt will increase compared with previous year.

Figure 6: Water spread area at different survey year for Hirakud reservoir at FRL

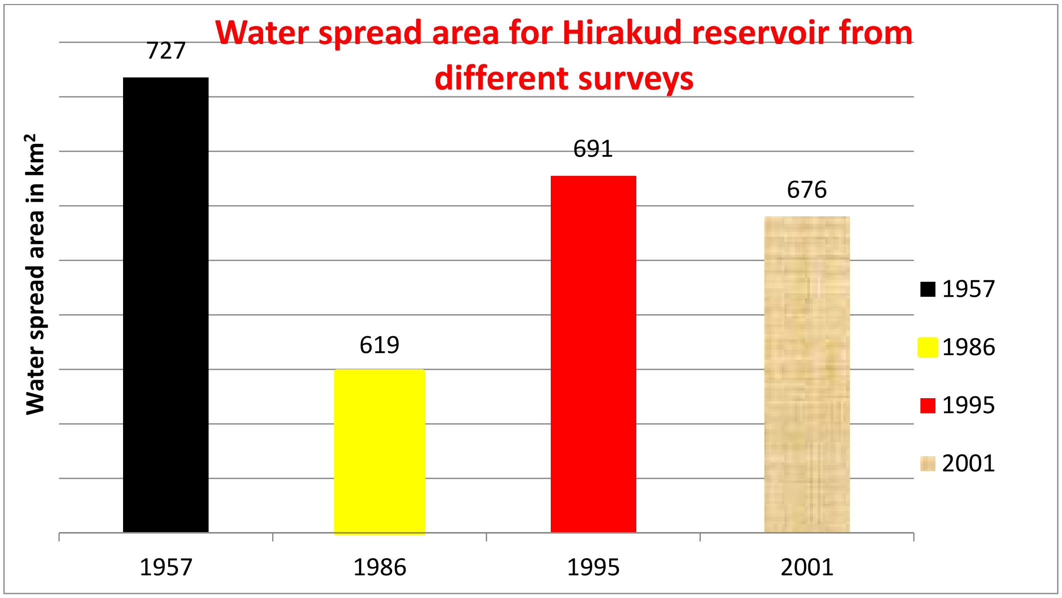


Figure 6 shows the water spread area at different survey years, the original water spread or the lake formed due to the reservoir in 1957 was 727 km^2. By 1986 the spread area decreased to 619 and again there was increase in water spread area in 1995 and 2001. Water spread at particular year is varying and fluctuating because there are many factors which affects the water spread area of the reservoir. The decrease in area is caused by sedimentation at the top dam level or in the banks of the reservoir and also because of less rainfall and runoff to the reservoir during the time of survey. The water spread picks up from year 1986 to 1995 at FRL and it might just well be because of high sedimentation at the bottom and lower level of the dam.

Figure 7: showing change in water spread area at MDDL for given years

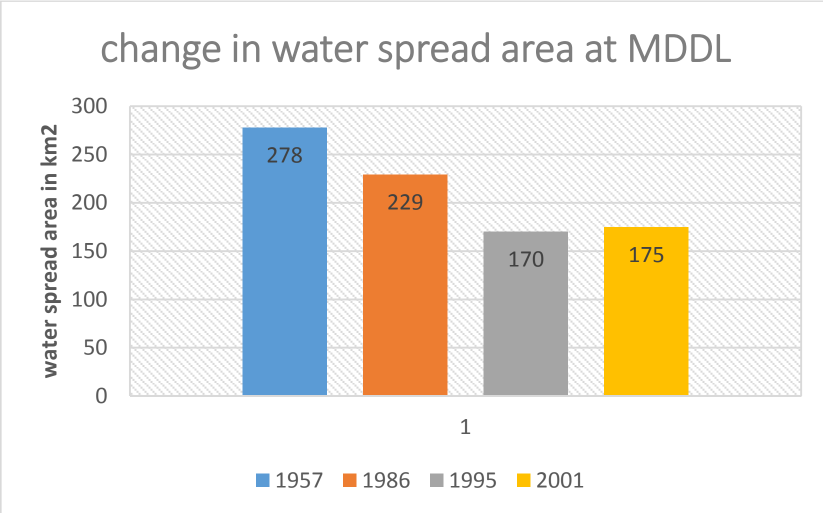


Figure 7 shows the change in water spread at MDDL (minimum draw down level), MDDL is the level below which the reservoir will not be drawn down so as to maintain a minimum head required in power projects. The MDDL of Hirakud dam is 179.83 meters and it is at the lower level of the dam. There is steady decrease in water spread at RL 179.83 m because of deposition of sediments at the sides of that level.

CHANGES IN WATER SPREAD OVER THE YEARS FROM 2004-2012

Methodology

Satellite data of September 30 2004, September 25 2005, September 29 2006, September 20 2007, September 15 2009, September 26 2010, September 29 2011 and 28 2012 were taken from google earth. The data taken were analyzed in ILWIS 3.3 to find the water spread area for the above given dates.

First the data obtained from google earth was imported in ILWIS 3.3 as BMP file. The segment map was drawn across the water boundaries and it was checked for the 3 important parameters:1) Self Overlap 2) Dead Ends 3) Intersections. If none of these are found then the data is polygonized and the polygonized section is saved. Closing the tab, returning to home and rick clicking the polygonized section we can view the water spread in as Area.

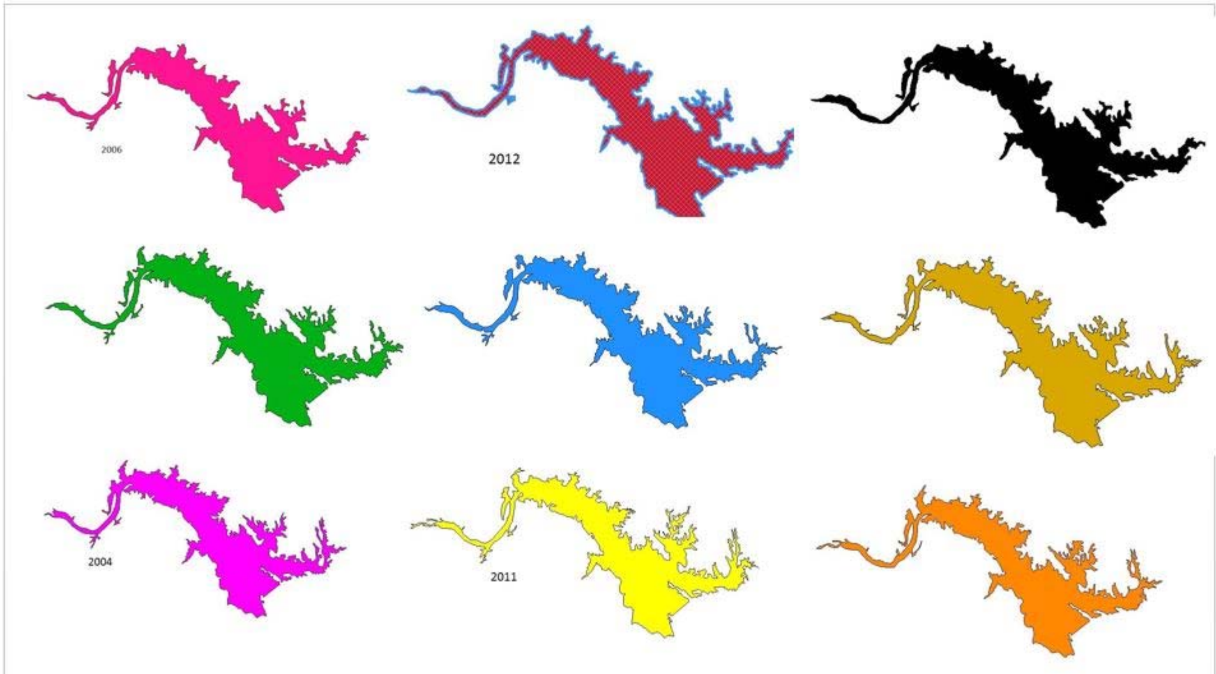
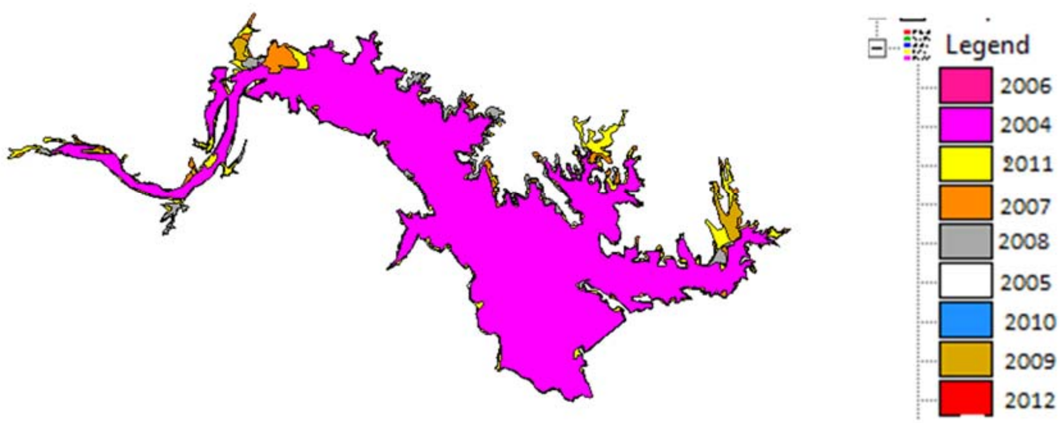


Figure 8: showing the outline water spread area obtained from ILWIS 3.3 software.



Water spread area obtained from ILWIS software for year 2004-2012 is given in Table 3:

Table 3: showing the water spread in km^2 from year 2004 to 2012

Year	Water spread area in km^2
2004	600
2005	700
2006	691
2007	699
2008	673
2009	686
2010	704
2011	708
2012	678

Table 3 shows the water-spread area of Hirakud reservoir from year 2004 to 2012. All the satellite data were at full reservoir level except for 2004 and 2009 in which the dam capacity didn't reach FRL. The reason for year 2004 having less water maybe well because it did not reach the full reservoir level.

CHAPTER 6

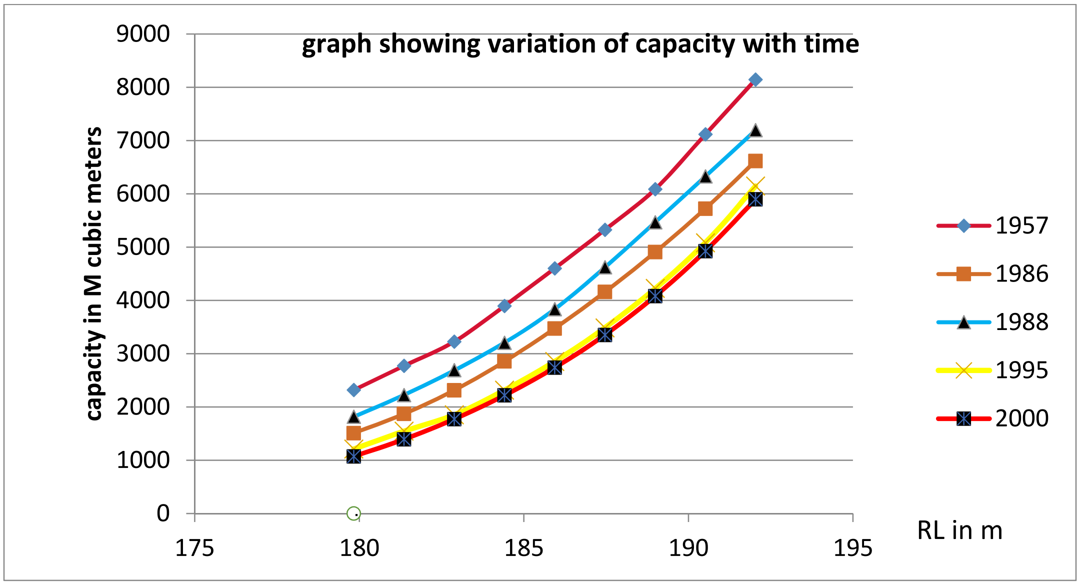
ANALYSIS OF REDUCTION IN CAPACITY OF HIRAKUD RESEVOIR

Every reservoir is designed with a purpose to serve something be it irrigation, drinking water, flood control or the power generation. The storage in the reservoir decreases with time because of sedimentation in bed. After dam is built, silt- laden water flows into the reservoir, causing siltation in both live storage and dead storage of the reservoir. Therefore utilizable water and benefits from the reservoir is reduced. During the construction of the dam we take a design silt index which defined as the rate at which sedimentation occurs. If the actual rate of sedimentation is higher than the design silt index then the life of the reservoir will be reduced. Due to sediment deposition and formation of delta, flow at mouth of small tributaries is blocked. Pools thus created, further reduce capacity of reservoirs.

Table 4: showing the reduction in water storage over the years at different reservoir levels

Reservoir Level	Original (1957)	1986(hydrographic survey)	1988	1995	2000
179.832	2318.304	1508.95	1815.685	1211.231	1073.129
181.358	2772.226	1871.074	2222.734	1546.137	1392.274
182.884	3226.147	2311.755	2691.457	1852.492	1771.851
184.41	3895.037	2854.937	3203.352	2316.051	2217.85
185.936	4600.93	3472.191	3834.895	2853.803	2738.109
187.462	5325.009	4157.604	4620.623	3483.604	3351.629
188.988	6086.092	4905.276	5465.558	4225.658	4080.553
190.514	7115.122	5721.101	6326.528	5080.889	4925.117
192.04	8136	6614.818	7193.666	6145.849	5896.565
Percentage decrease in capacity at FRL	0	18.778%	11.67%	24.54%	27.604%

Figure 9:Graph showing the reduction in capacity with time or age of the reservoir



The total reservoir storage at full reservoir level in 1957(year at which it first functioned) was recorded to be 8144 M m^3. When the second hydrographical of Hirakud reservoir was taken up the capacity at FRL reduced to 6614 M m^3, which means there is loss of 1529 M m^3 in 29 years. There was 18.78% decrease in capacity in 29 years. When the latest survey was taken up by the Hirakud dam officials, the data shows that the reservoir capacity in year 2000 was reduced to 5896 M m^3 with 27.604 % decrease in capacity in 43 years.

CHAPTER 7

SEDIMENTATION AND THEIR AFFECT ON THE STORAGE VOLUME OF HIRAKUD RESERVOIR

Sediments are defined as the fragmental earth materials eroded, transported and deposited elsewhere by air and water. Sediment transportation being a natural process it cannot be stopped completely. The problems of sedimentation are 1) erosion of the place of origin 2) transportation of sediments through river water and 3) deposition of sediments in the reservoir which we are really interested in when it comes to the study of reservoir.

Reservoir sedimentation

Transportation of sediment by river and their deposition in the reservoirs depend on flow conditions, type of sediments and their interaction with each other. When river water enters a reservoir, the velocity decreases because of increased cross-sectional area through which it passes. The decrease in in velocity leads to the sediment deposition sediment deposition at the bottom of the reservoir under the action of gravity. Sedimentation surveys for Indain reservoirs show that the rate of sedimentation vary from 4.75 to 14 Ha.m/100 km^2/year. Most of the reservoir lose 0.5-1 % of their storage capacity to sedimentation every year. Indian Standard (IS 6158-1972) recommends a provision of 10-20 Ha.m/100 km^2/year of sedimentation.

Various problems in the process of sedimentation of reservoir

1) Uncertainty of area occupied by sediment in the reservoir
2) Lack of knowledge regarding the contribution of sediment by water from the catchment.
3) Variability of sediment inflow from year to year and season to season
4) Not knowing the reservoir operation schedule
5) Varying in reservoir capacity to inflow ratio

Sedimentation analysis for Hirakud reservoir

Table 5: Showing sedimentation estimated using hydrographic and remote sensing surveys

Sedimentation for live storage in units of	1957-1986	1957-1995	1957-2001
M m^3	720.00	924.53	984.47
M m^3 per year	24.00	23.71	21.88
% of live storage	12.36	15.87	16.90
% of live storage $year^{-1}$	0.412	0.407	0.376
Ha. m (100 km^2 $year)^{-1}$	2.878	2.842	2.623

Table 5 shows the sedimentation rates in live storage for years 1957-1986, 1957-1995 and 1957-2001. The total live storage loss between 1957 and 2001 was 984 M m^3.The total loss in storage was 16.90% and yearly live storage of 0.376%. The silt index for live storage zone was found to be 2.623 Ha.m(100 km^2 $year)^{-1}$

The live storage capacity estimated using remotely sensed data for Hirakud reservoir, was 4842 M m^3 in year 2001. During 44 years, live storage capacity was reduced by nearly 17 % (at the rate of 0.376 % per year) of live storage. Silt index for live storage area was 2.623 Ha.m (100 km^2 year)$^{-1}$. This rate though low was more than the design rate which was 2.5 Ha.m (100 km^2 year)$^{-1}$.

Reservoir sediment control

The following are some ways to reduce the sedimentation in any reservoir

I. The reservoir site should be chosen in such a way that there are reservoir facilities available and where the chances of sediment load coming can be minimum.
II. Provide under sluice below the probable height of deposition of silt, this helps to remove some quantity of sediment from the reservoir.
III. Construct minor check dams in the upstream catchment where soil erosion potential is maximum, by doing this the sediment inflow into the downstream main reservoir can be checked
IV. Adopt soil conservation methods like tree plantations, control grazing in catchment, terracing the land, benching, cover cropping through which we can reduce the erosion
V. Lastly the silt can be excavated or dredged in small reservoirs or tanks but it doesn't come economical.

CHAPTER 8

DEVELOPMENT OF AREA CAPACITY CURVE FOR THE YEAR 2012

Methodology

A set of satellite data were taken from the google earth to analyze, satellite map of 5th July corresponding to RL 179.832, similarly of 20th June (RL 181.356 m), 30th May (RL 182.88 m), 6th May (RL 184.404), 14th April (RL 185.92 m), 14th March (RL 187.452 m), 28th January (RL 188.976 m), 11th September (RL 190.5 m) and data of 5th October (RL 192.024 m).

The format of image obtained from Google Earth is changed to either BMP or TIFF. The images were imported to ILWIS 3.3 software and segment map is drawn to separate water from land in the data. The segment drawn was checked for the 3 important parameters:

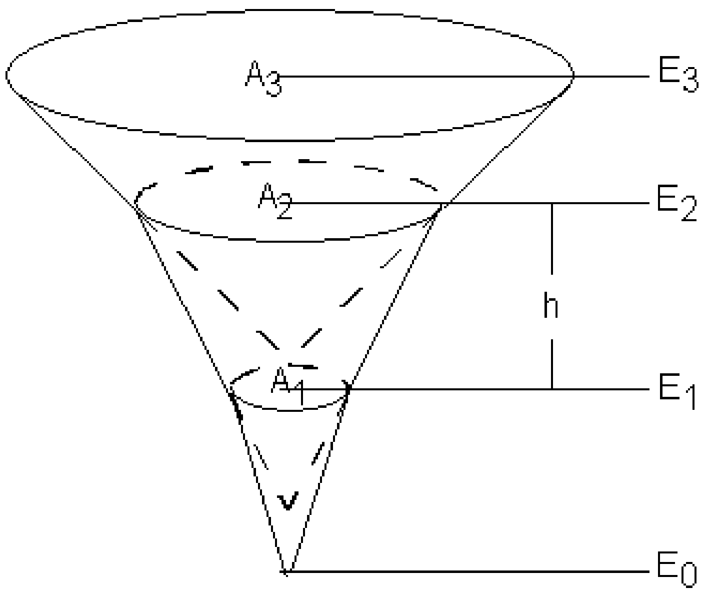
1) Self Overlap 2) Dead Ends 3) Intersections. If none of these are found then the data is polygonized and the polygonized section is saved. Closing the tab, returning to home and rick clicking the polygonized section we can view the water spread in as Area.

After obtaining the water spread at different reservoir levels, capacity or the storage is computed using cone formula which is given by:

Cone formula

If Area vs Elevation or reservoir is given/specified, then the corresponding volume for each elevation is computed using the conic method. The conic method is illustrated below.

Figure 10: diagram showing the development of cone formula



The volume between two successive areas A_1 and A_2 is computed using the equation given below

V=h/3(A1+A2+sqart (A1+A2)

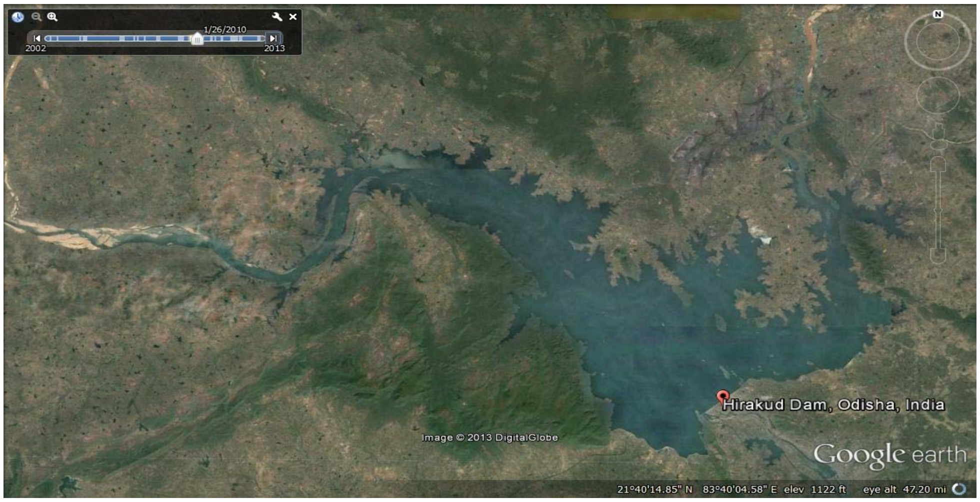
Where,

V= volume between A1 and A2 which is same as between E1 and E2

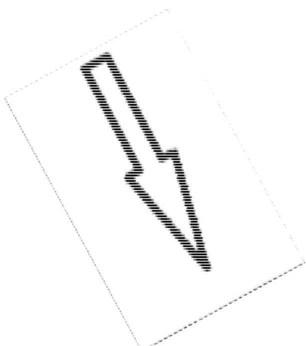
A1 and A2 = Area at elevation E1 and E2 respectively

h=elevation difference (E2-E1)

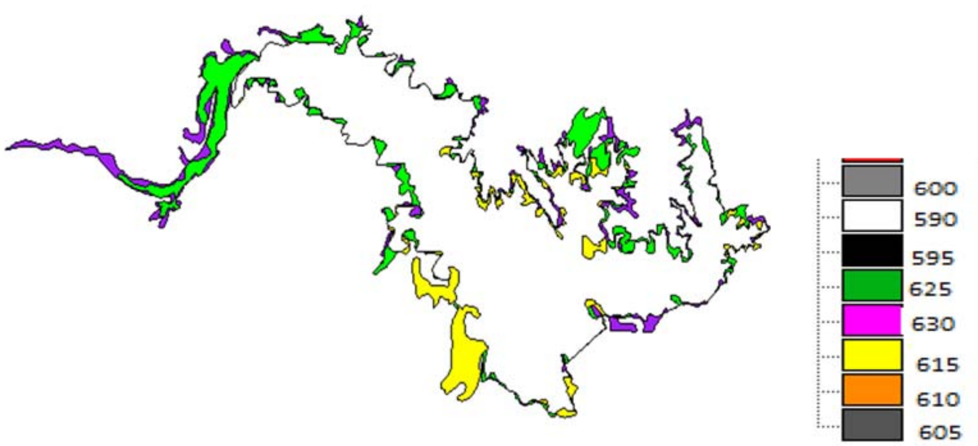
Figure 11: picture showing the satellite data to polygonized image to find water spread area



<u>Google Earth image</u>



Polygoized image obtained from ILWIS 3.3



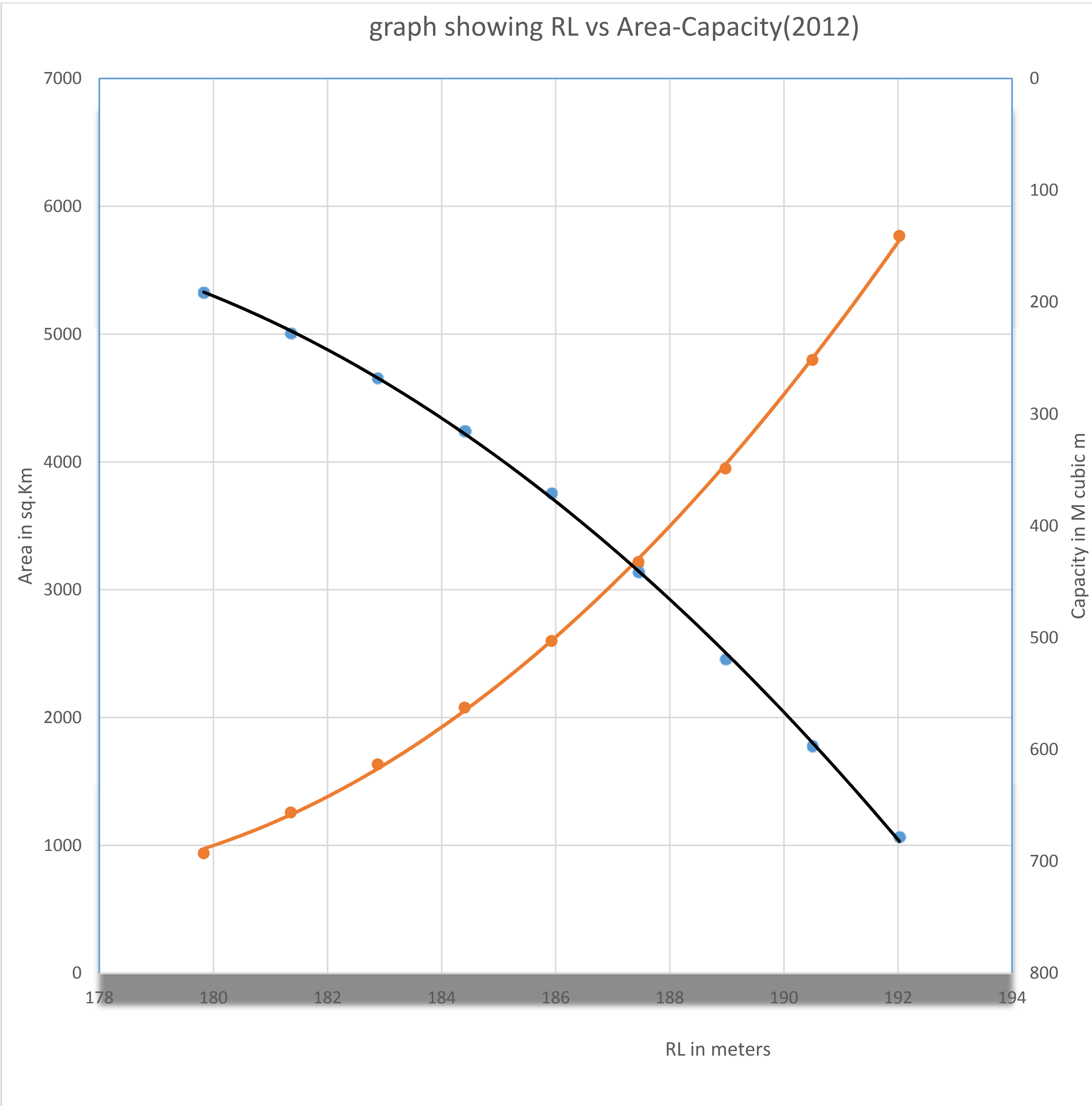
Result obtained

Reservoir level in meters	Water spread area obtained From ILWIS (Km^2)	Capacity (in M m^3)
179.832	191.19	938.82
181.356	227.607	1257.54
182.88	267.77	1634.6
184.404	315.025	2078.2
185.928	370.62	2600.089
187.452	441.2	3217.915
188.976	519.1	3948.855
190.5	596.64	4798.363
192.024	678	5768.653

Table 6: Reservoir level to Area-capacity table obtained from ILWIS and by using cone formula

Reservoir Level vs Area-Capacity curve for year 2012 of Hirakud Reservoir

Figure 12: Graph showing RL vs Area-capacity curve for year 2012



CHAPTER 9

COMPARISON OF RESULTS

Table 7: Table showing comparison between results obtained for 2012 with original provision of 1957

R L(m)	original provision(1957)			ILWIS analyzed (2012)		
	Area (Km2)	Capacity M. m^3	cumulative capacity	Area (Km2)	Capacity M. m^3	cumulative capacity
179.832	277.66	405.26	2262.12	191.19		938.82
181.356	322.09	456.59	2718.71	227.607	318.72	1257.54
182.88	366.58	524.36	3243.07	267.77	377.06	1634.6
184.404	416.49	596.26	3839.33	315.025	443.6	2078.2
185.928	466.46	672.45	4511.78	370.62	521.889	2600.089
187.452	525.5	754.66	5266.14	441.2	617.826	3217.915
188.976	582.5	843.13	6109.17	519.1	730.94	3948.855
190.5	651.97	942.37	7051.94	596.64	849.508	4798.363
192.024	727.31	1053.06	8135.15	678	970.29	5768.653

Figure 13: graph showing comparison of capacity in 2012 to original provision for Hirakud Reservoir

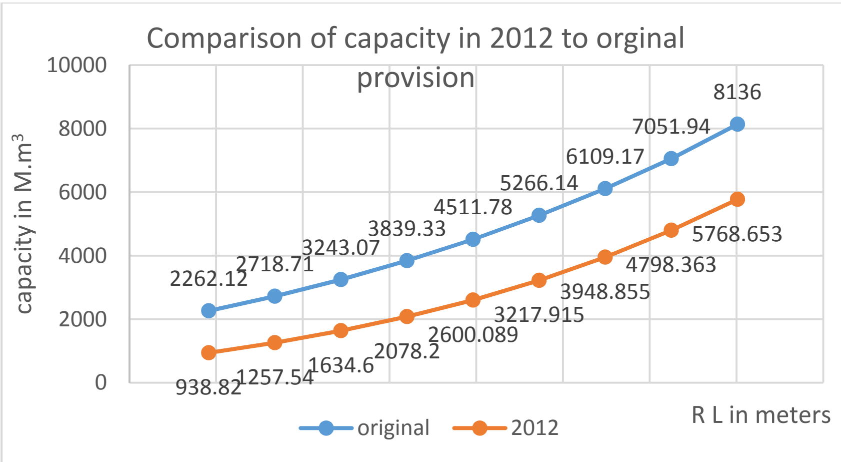
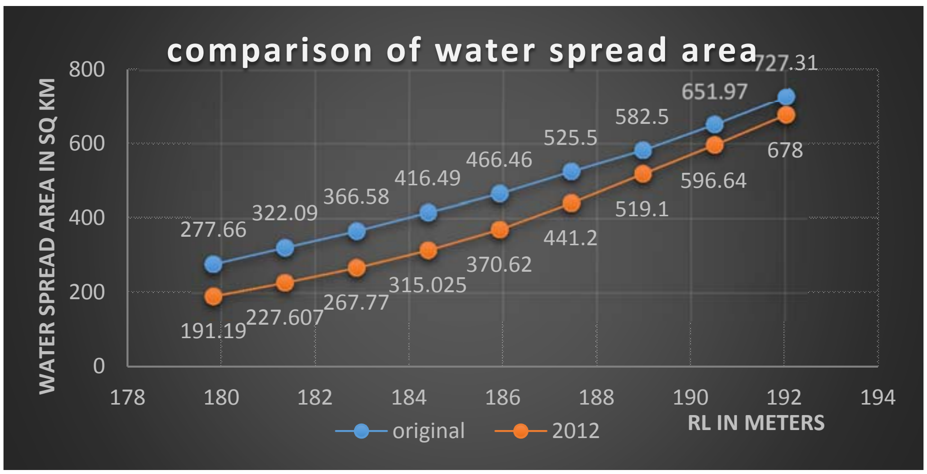


Figure 14: graph showing water spread difference between year 1957 and 2012



The storage capacity at full reservoir in 2012 was analyzed to be 5768 M m^3, thereby showing decrease in capacity by 2368 M m^3 that is 29.105 % of gross capacity.

Live storage in 1957 was estimated to be 5826 M m^3 and the live storage in 2012 is calculated as (5768-938) which is equal to 4830 M m^3

The water spread area at FRL in 1957 was 727 km^2 and this study shows that the water spread area has decreased to 678 km^2. Also there is decrease in water spread are at MDDL from 277 km^2 to 191 km^2.

Water spread area and capacity at different reservoir level for different surveys in Hirakud reservoir

Table 8: Area capacity chart for Hirakud reservoir

RL (m)	**1957(Original)**			**2^{nd} Sedimentation(1982)**			**Hirakud collected (2000)**			**Analyzed(2012)**		
	Area (Km2)	Capacity	Cumm-ulative	Area (Km2	capacity	Cu-ulative	Area (Km2	capacity	Cumm-ulative	Area (Km2	capacity	Cumm-ulative
166.1				15.87	15.48	24.06						
167.6	42.97	366.28	366.28	39.33	40.77	64.83						
169.2	70.56	86.48	452.76	50.32	68.19	133.02						
170.9	97.15	127.25	580.02	60.68	84.51	217.33						
172.2	115.67	161.96	741.98	104.03	124.12	341.6						
173.7	134.18	190.21	932.19	134.34	181.27	522.92						
175.3	182.62	240.45	1172.64	146.76	210.81	733.73						
176.8	231.05	314.49	1487.13	157	228.19	961.92						
178.3	254.35	369.73	1856.86	177.97	255.42	1217.34						
179.8	277.66	405.26	2262.12	215.92	299.88	1517.22	193.1471		1073.122	191.19		938.82
181.4	322.09	456.59	2718.71	256.51	354.78	1877	232.3002	308.88	1392.265	227.607	318.72	1257.54
182.9	366.58	524.36	3243.07	311.55	432.47	2309.47	273.4605	379.5053	1771.77	267.77	377.06	1634.6
184.4	416.49	596.26	3839.33	369.6	578.75	2328.22	320.9784	446.0648	2217.835	315.02	443.6	2078.2
185.9	466.46	672.45	4511.78	477.25	621.91	3460.13	372.2072	520.2558	2738.091	370.62	521.889	2600.089
187.5	525.5	754.66	5266.14	481.58	708.08	4158.21	445.5965	613.5163	3351.607	441.2	617.826	3217.915
188.9	582.5	843.13	6109.17	527.05	768.83	4927.04	525.837	728.9189	4080.526	519.1	730.94	3948.855
190.5	651.97	942.37	7051.94	536.24	810.76	5737.8	598.9713	844.5583	4925.084	596.64	849.508	4798.363
192.0	727.31	1053.06	8105	630.1	888.61	6626.41	695.0431	971.442	5896.526	678	970.29	5768.653

Discussion

The reservoir capacity at full reservoir level was found to be 5768.63 M m^3 compared to 8136 M m^3 at the time when it first functioned. The total decrease of 2368 M m^3 in 55 years,

The water spread area is 678 Km^2 to 743 Km^2 at full reservoir level at the time of construction.

The capacity of the reservoir obtained by cone formula for year 2012 was found to be 5768 M cubic meters compared to 5896 M cubic meters in year 2000

The water spread area has shown variations , it is sometimes less and sometimes more , this is mainly due to amount of rainfall and inflow and outflow in that year.

BIBLIOGRAPHY

1. Nayak . B. N. (2006), An analysis using LISS iii data for estimating water demand for rice cropping in parts of Hirakud command area, indian institute of remote sensing national remote sensing agency, department of space, government of india dehradun, pp 2-69

2. Rathore *et al.(* 2006), Assessment of sedimentation in hirakud reservoir using digital remote sensing technique, journal of the Indian Society of Remote Sensing, **34**, pp

3. Muhaerjee *et al.*/Josh(2007) ,Sedimentation Study of Hirakud Reservoir through Remote Sensing Techniques, Journal of Spatial Hydrology, **7,** pp 122-130

3. Report of high level technique committee (2007), to study various aspects of water usage For Hirakud reservoir, government of Orrisa, water resource department

4. Kaveh. k, Hosseinjanzade. H, and Hosseini .K (2012),A New Equation for Calculation of Reservoir's Area-Capacity Curves, Korean society of civil engineers, pp 1-8

5 . Patra K.C, hydrology and water resource engineering , Rourkela, Narosa, 2010

6. McPherson K. R., La Freeman A, and Flint L. E.(2009) Analysis of method to determine storage capacity of and sedimentation in loch lomond :pp 1-94

7. Kharagpur IIT, lesson 5 planning of water storage reservoirs version ,**5,** pp 1-44

8. Choudhury P, Sandbhor J, Satapathy P (2012), floods, fields and factories; towards resolving conflicts around the Hirakud dam, odhisa resourse state centre, pp 1-247

9. Srivastava1 P K, Majumdar T J,and Bhattacharya1 A K, Study(2010) of land surface temperature and spectral emissivity using multi-sensor satellite data, Indian Academy of Sciences, pp 67-74