Assessment and Management of Sedimentation in Kundah Reservoir – A Case study

Presented by

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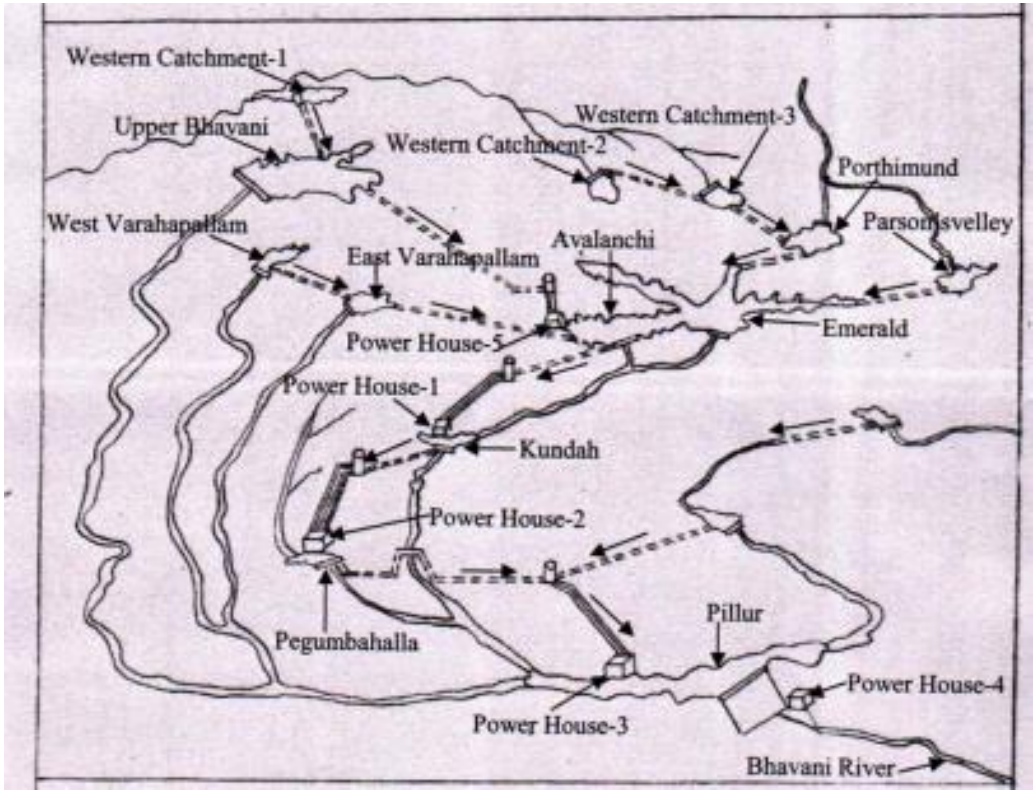
INTRODUCTION

- Reservoir Sedimentation is a process initiated by erosion of soil in the catchment area either natural or accelerated.
- It is greatly influenced by watershed characteristics, uncontrolled deforestation, forest fires, over grazing etc.
- It is an indispensable process in reservoirs .
- Even though, the reservoirs are designed to accommodate the sediment deposition in the form of dead storage, due to sedimentation the useful life of the reservoir and storage capacity is reduced considerably.
- Periodical capacity surveys of reservoirs help in assessing the rate of siltation and to evolve suitable catchment area treatment to control sedimentation process

PROJECT AREA

- The Kundah Hydro-Electric project is the biggest Hydro-electric scheme in the state
- It consists of six reservoirs namely, Upper Bhavani, Emerald-Avalanchi, Parson's valley and Porthimund, Kundah, Pegumbahalla and Pillur.
- Kundah reservoir is one among the Kundah Hydro electric group of reservoir.
- The installed capacity of power house in Kundah is 175 MW
- It is situated in a fairly steep gorge near a place called Kundah Pallam in Nilgiris district
- The project area receives an annual rainfall of about 1400mm, distributed over 190-220 days,

Flow Diagram of Kundah group of Reservoirs



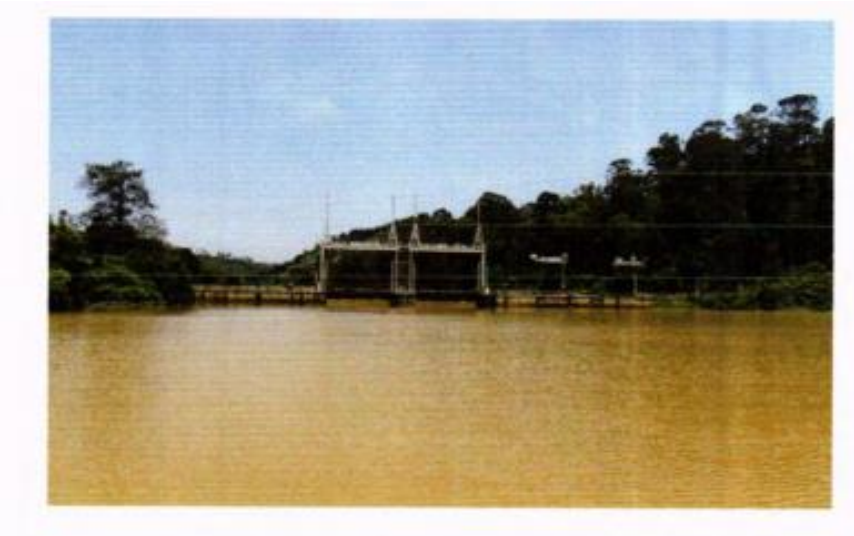
Not to scale

KUNDAH PALLAM DAM

- It is a straight masonry gravity dam constructed across Kundah river just below the Canada Power House No.1

Catchment area	:	**113.96 Sq.km**	**F.R.L and M.W.L**	:	**+1625 m**
Length of the dam	:	170.73 m	M.D.D.L	:	+1609.34 m
Height of the dam from deepest foundation	:	32 m	Scour vent sill Level	:	+1599.39 m
Top level of the dam	:	+1626.52 m	Deepest bed level	:	+1597.87 m
Top width of the dam	:	4.57 m	Spillway arrangements	:	2 lift type gates,
Gross capacity	:	1.76 M.cum	Spillway discharge	:	1556.5 cumec
Effective capacity	:	1.56 M.cum	Spillway gate size	;	12.2m x 9.14m
Water spread area at FRL	:	0.166 sq. km	Power house capacity	:	175 MW

Kundah- Front view



Kundah- Rear view

SEDIMENTATION STUDY IN KUNDAH

- Two capacity surveys were done during 1977 and 1982.

- The third capacity survey was done during 2015 under Dam Rehabilitation and Improvement Project – I, which had been implemented in Tamil Nadu during 2012-2021.

- The above study was carried out by Water Shed Management Board, a separate wing of Tamil Nadu Water Resources Department

SEDIMENTATION STUDY PROCEDURE

1. Preparation of Base Map
2. Reconnaissance, Fixing of range lines and erection of range pillars
3. Triangulation survey and fixing the position of range pillars on base map
4. Levelling to find out the elevation of base pillars.
5. Hydrographic survey & Ground survey
6. Collection of soil samples along the range lines and analysis.
7. Preparation of contour map for the present survey
8. Computation of present capacity and silting rate

INCOLD
Indian National Committee on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE

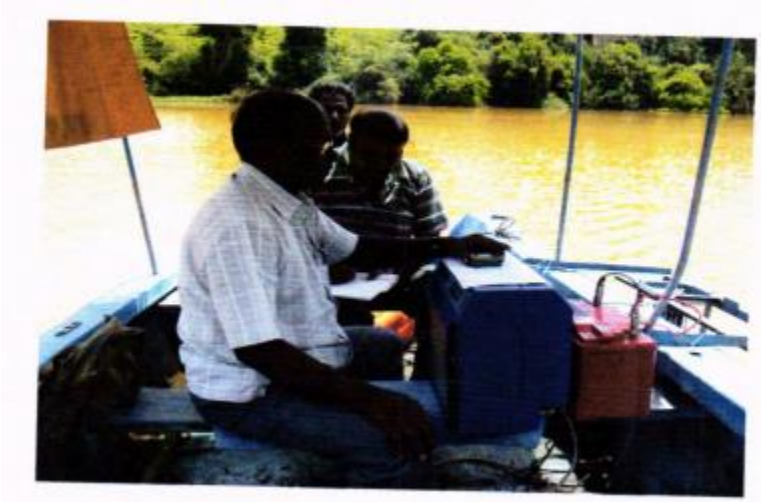
DRIP
Dam Rehabilitation & Improvement Project

Central Water Commission

Fixing of range pillars

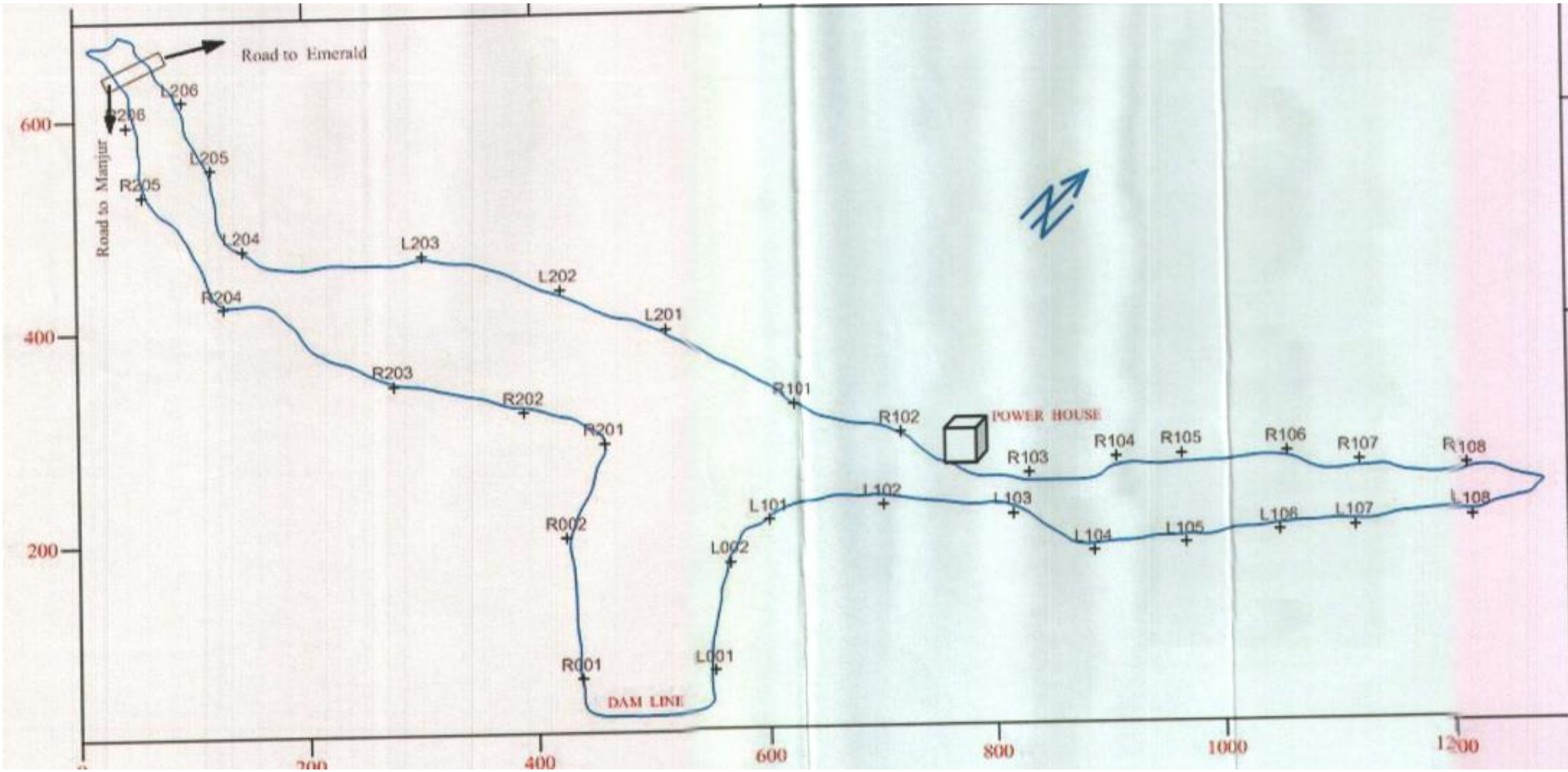
Triangulation survey- Baseline fixing

Triangulation survey network



Hydrograhic survey

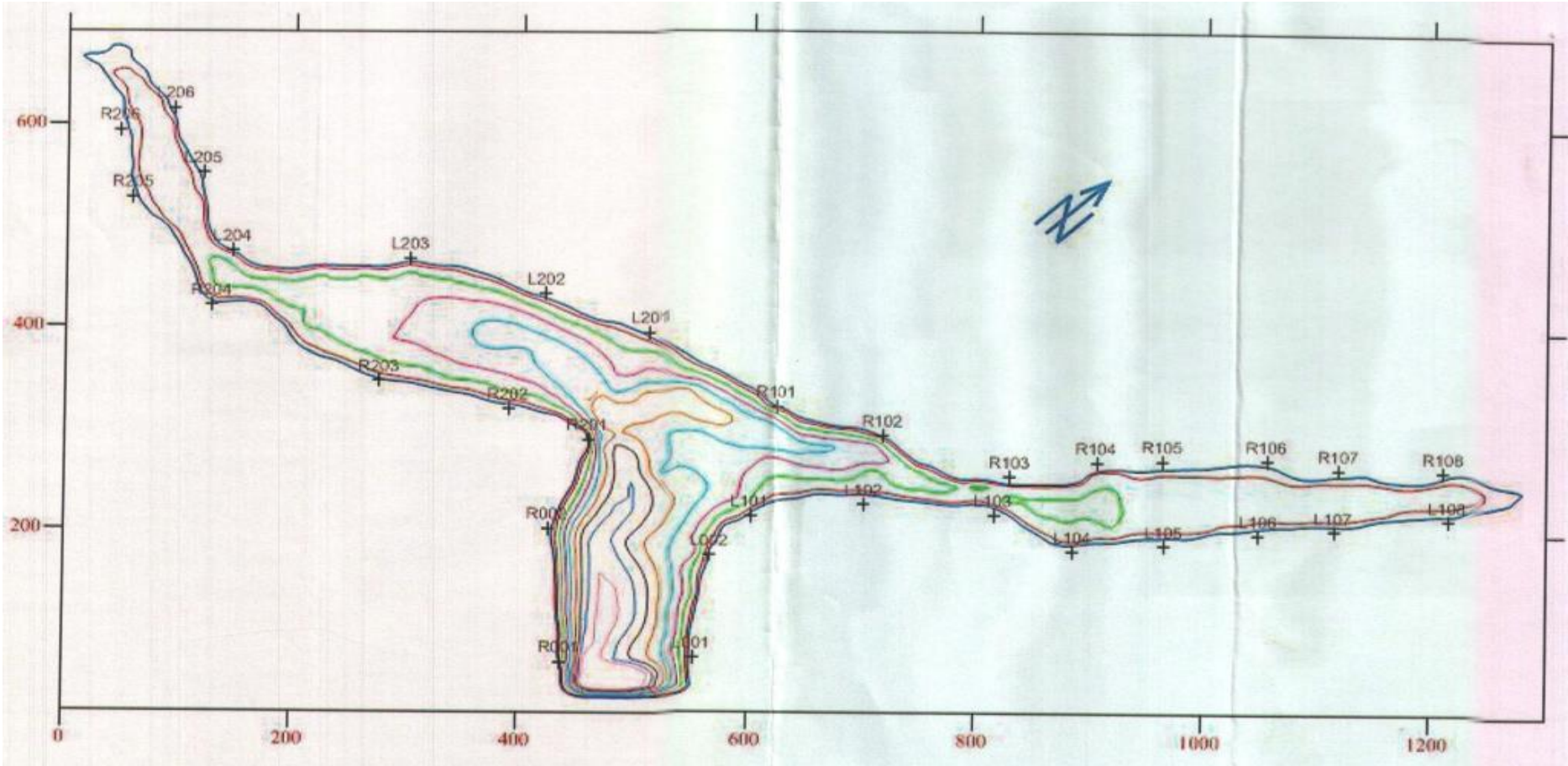
10-12 October 2022 at Jaipur, Rajasthan (India)



Water shed map showing the location of range pillars and power line

Procedure Contd….

- 17 range lines were fixed & 34 range pillars were erected along the periphery of FRL line for triangulation survey by total station.
- Hydrographic survey has been conducted using BATHY 500 single beam Echo Sounder to measure the water depth and the present bed level was found out.
- The present water spread area map of Kundah reservoir was prepared in the scale of 1:4000 using the Surfer version 8 Software.
- This map has been used as the base map for developing the elevation – area – capacity relationship of Kundah reservoir and the present capacity of the reservoir was found out.


600
400
200
0
200
400
600
800
1000
1200
L206
L205
L204
L203
L202
L201
R203
R202
R201
R101
R102
R103
R104
R105
R106
R107
R108
L101
L102
L103
L104
L105
L106
L107
L108

Contour Map

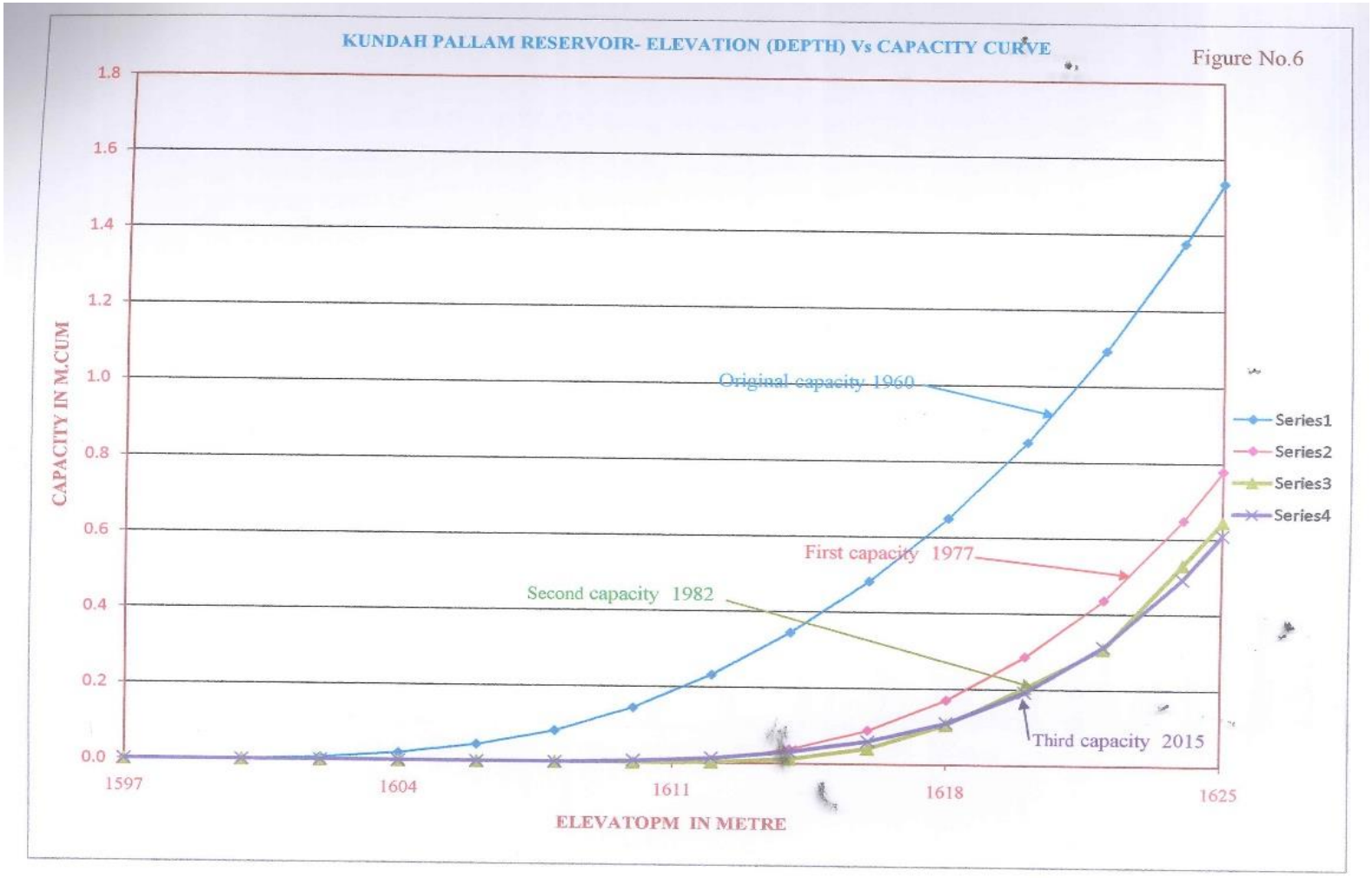
ANALYSIS OF DATA

Sl.No	Description	1st Capacity Survey(1977)	2nd Capacity Survey(1982)	3rd Capacity Survey (2015)
1	Water Spread Area in sq.km	0.1336	0.1179	0.1275
2.	Sedimentation Rate in M.Cum/sq.km	0.00683	0.00567	0.00535
3	Capacity in M.cum	0.778	0.646	0.609
4.	Capacity / Inflow ratio	0.01	0.009	0.0105
5	**Silt Deposition in 2015**			**0.9241 M.cum**
6	Average Annual silt Load (for 54 years)			0.017 M.cum
7	Silt deposition in %			60.24%
8	Average Annual silting Rate			1.12%
9.	Average annual silting rate/sqkm catchment			0.000149M.cum/sq.km

KUNDAH PALLAM RESERVOIR - STATEMENT OF CAPACITY TABLE

S.No	Contour level in metre	Capacity in M.cum				Remarks
		Original Capacity during 1960	First Capacity Survey during 1977	Second Capacity Survey during 1982	Third Capacity Survey during 2015	
1	1597.87	0.00000	0.00000	0.00000	0.00000	
2	1600.00	0.00184	0.00000	0.00000	0.00000	
3	1602.00	0.00685	0.00000	0.00000	0.00000	
4	1604.00	0.02021	0.00000	0.00000	0.00000	
5	1606.00	0.04395	0.00000	0.00000	0.00000	
6	1608.00	0.08208	0.00000	0.00000	0.00000	
7	1610.00	0.14463	0.00010	0.00020	0.00515	
8	1612.00	0.23287	0.00880	0.00310	0.01366	
9	1614.00	0.34531	0.03800	0.01340	0.03145	
10	1616.00	0.48228	0.08970	0.04200	0.06028	
11	1618.00	0.64978	0.17090	0.10580	0.11004	
12	1620.00	0.85173	0.28690	0.20560	0.19243	
13	1622.00	1.09290	0.43700	0.30840	0.31294	
14	1624.00	1.37577	0.64890	0.53120	0.49310	
15	1625.00	1.53432	0.77840	0.64620	0.60995	FRL

ELEVATION VS CAPACITY



- During the third capacity survey, the capacity of the reservoir increased up to the elevation +1618 m when compared that of second capacity survey and after the elevation +1618 m the capacity decreased.

- Totally, the capacity of the reservoir decreased by 0.036 M.cum when compared to second capacity survey and 0.924 Mcum when compared to the Original capacity of the reservoir, when the elevation is at FRL/MWL (i.e)+1625 m.

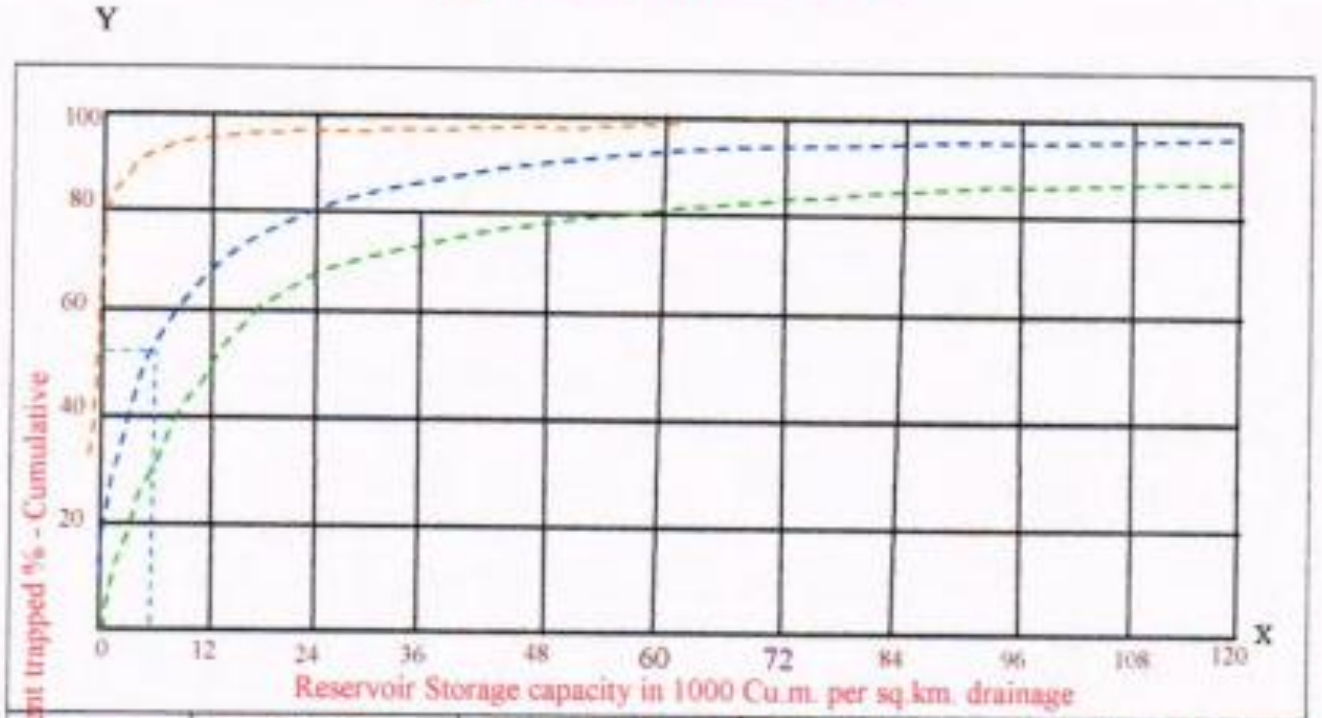
Trap Efficiency

- The Trap Efficiency of a reservoir is defined as the ratio of the quantity of deposited sediment to the total sediment inflow i.e the percentage of incoming sediment trapped.
- The trap efficiency of the Kundah reservoir as per Gunner M.Brune and as per Gottah Chalk curve are tabulated in Table below.

Study details	As per Gottah Chalk	As per Gunner M.Brune
Trap Efficiency as per Original capacity (1960)	66.0 %	60.0 %
Trap Efficiency as per First capacity survey (1977)	54.0 %	43.0 %
Trap Efficiency as per Second capacity (1982)	52.5 %	40.0 %
Trap Efficiency as per Third capacity (2015)	54.0 %	46.0 %

KUNDAH RESERVOIR
TRAP EFFICIENCY CURVE
(By Gottachalk and Gunner M.Brune)

Figure No.9



Year	Capacity in M.cu.m	Watershed Area in Sq.k.m	Capacity/Watershed Ratio	Sediment Trapped In Percentage
1977	0.778	113.96	0.006827	54.0
1982	0.646	113.96	0.005669	52.5
2015	0.609945	113.96	0.005352	54.0

Life of Reservoir

- Life of the reservoir is the period of its usefulness for the designed purpose. It depends on the rate of sedimentation. To assess the life of the Reservoir, Dr.Hachiro Kira of Khagwa University has developed an equation taking into account inflow is as follows:

Vs = 0.214(c/i)-0.473

Ys= 100 / Vs

Ys=467(c/i)^0.473

Where Vs = Annual mean silt deposition rate in percent

i = Annual mean inflow into the reservoir in mm^3

c = Original capacity of the reservoir in mm^3

Ys = Number of years during which the silt will fill up the reservoir completely

Ys = 83.7 or 84 Years

Hence, the life of the reservoir is 84 years.

Collection of Soil Samples and analysis

- One of the important point of reservoir sedimentation survey is the collection of soil samples and their analysis.
- Sediment samples will give an idea regarding the type of sediment, source of sediment etc. Ten number of soil samples were collected along the range lines in the waterspread area. The samples were analysed using the sieve shake hand operation machine.
- By weighing the particles retained in the sieves, the percentage of the particle size of the samples were measured.
- From this, the classification of soil samples chart and percentage of soil distribution curves were prepared.
- From analysis, it is seen that the sediment contains a maximum of 47.25% Medium sand (75 microns) and a minimum of 1.27% Fine sand (63 microns). The remaining particles size are Gravel 2.26%, coarse sand 46.30% and Silt 2.92%.


KUNDAH RESERVOIR
CLASSIFICATION OF SOIL GROUPS CHART
Figure No.14
Percentage of soil retained
80
70
60
50
40
30
20
10
0
Series1
Series2
Series3
Series4
Series5
Series6
Series7
Series8
Series9
Series10
Gravel
100 - 2 mm
Course sand
600 - 212 mic
Medium sand
75 mic
Fine sand
63 mic
Silt & Clay
Retained
Soil type / particle size

Results of Sedimentation Study

Original capacity in M.cu.m	1.534
Present capacity in M.cu.m	0.609945
Capacity loss in M.cu.m	0.924055
Capacity loss in %	60.24
Annual storage loss in %	1.12
Life of reservoir in years	84
Trap efficiency	54%
Rate of sedimentation in % per annum	1.737

Measures to increase the useful life of Reservoir

- To increase the useful life of the reservoir, the trapped sediment in the reservoir is to be removed or the sediment transport to the reservoir is to be minimized through catchment area treatment works.
- The second part of the paper described the catchment area treatment works carried out by the Agricultural Engineering Department under DRIP- I in Kundah reservoir for sediment management and its effectiveness.

SOIL CONSERVATION MEASURES

- To control the reservoir sedimentation the soil erosion is to be checked at its sources through specific structures at vulnerable sites.
- The vulnerable locations are identified by superimposing the different thematic maps prepared such as drainage map, soil map, lineament map, geology map of the catchment

Soil Conservation Measures

- **Terrace support wall / Facial revetment** - To protect terraces soil slips, Terrace support wall / Facial Revetment for a length of 2950 mts was constructed in the agricultural field wherever necessary and along the cut face of the road, stream banks etc., in the catchment

- **Gabion Terrace support wall / Gabion Facial revetment** - To protect terraces soil slip, Gabion Terrace support walls / Gabion Facial revetment was constructed for a length of 1489 mts.

Remedial Measures contd…

Upper reaches - Gabion Drops Gabion drops are constructed in the steep slopes of the upper reaches of the gullies where ever sudden drops in the bed slopes are noticed.

Middle Reaches - Gabion Check Dam Gabion check dam are constructed in the middle and lower reaches of the gullies. The Gabion structures intercept the gully flow and thereby reduce the velocity of water and helps safe deposit of silt and also prevent the enlargement of gullies.

Remedial Measures-Lower Reaches

a) Channel alignment and Widening

The narrow river courses are to be widened in the lower reaches where the existing river beds are raised due to deposition of silt carried by the stream which result in flooding over nearby cultivated fields. It was proposed to deepen and widen of the streams to a length of 14948 m. in the catchment.

• Bed Dam

The Bed dams are constructed in the lower reaches of gullies where ever the gullies have widened so as to impound the runoff water and to arrest the movement of silt.

Remedial Measures-Silt detention structure

- During the flash floods large amount of silt is carried through the streams and is arrested by construction of silt detention structures. These structures help impounding the run off from the nearby field through streams and the farmers can also use the deposited silt in their fields as they are rich in nutrients

Remedial Measures

- **Land slide Treatment works**

Landslides are of frequent occurrence, due to the thickness of the weathered rocks and presence of steep hill slopes, the rate of soil creep and erosion is pronounced at places along the steep hill slopes, road sections and stream courses. Masonry structures were constructed to control landslides in the catchment

- **Silt Monitoring Station**

The Silt Monitoring Station constructed across the gullies in the lower reaches of the micro watershed. These are Monitoring Stations to monitor the Silt content in the runoff which reflects the behaviour of the Watersheds over a period of time for varying rainfall runoff situations. Thus the Soil Loss/hectare/annum from the micro watershed could be computed. One silt monitoring station was constructed in Silla halla watershed.

Impact of Catchment Area treatment works in the Kundah Dam

- No. of Silt Detention Tanks (SDT) constructed – 45 Nos
- Quantity of Silt retained per SDT = 126.00 cu.m /filling/SDT
- Total No. of fillings per year = 4 Nos
- Total Quantity of Silt retained in all the SDTs per year = 126 x 4 x 45 = 22,680 cu.m/year
- Assuming Bulk density of sediment as 1.2 Tons/cu.m
- Water equivalent to the sediment is 27,216 Tons/year or 27,216 cu.m/year of water= 0.96 MCft.(0.027M.cum)

Benefits of AED Interventions are:

- 22,680 cu.m/year of fertile top soil is prevented from erosion
- A quantity of 0.96 MCft water storage has been ensured for water filling by avoiding siltation

CONCLUSION

- Soil erosion and Sedimentation is a continuous process
- Hence, periodical assessment of the sedimentation rate and appropriate management measures are essential for improving the useful life of the reservoir as well as optimum reservoir operation schedule.
- From the Sedimentation analysis done in the Kundah reservoir it has been found that the loss in capacity is 0.924 M.cum (60.24%).
- As an outcome of the Catchment Area Treatment works done in the Kundah Catchment, 22,680 m^3 siltation has been reduced per year and 0.96 Mcft of water storage has been ensured.


THANK
YOU !