Government of Goa
Executive Engineer, Works Division III
Water Resources Department
Ponda, Goa

"Sedimentation Survey Report of Anjunem Dam under NHP"

Survey Period: 6th February to 9th February, 2021

Surveyed by:-

Advance Land & Hydrography Survey India Pvt. Ltd.,
Vichitra SP-46, Kolkata West International City,
Salap Junction, Howrah Amta Road
& Bombay Road Crossing, NH-6,
Howrah -711403, W.B

ACKNOWLEDGEMENT

Advance land & Hydrography Survey India Pvt. Ltd. expresses its gratitude to Water Resources Department, Government of Goa for awarding the work of carrying out **“Sedimentation Survey Report of Anjunem Dam under NHP”.**

The successful completion of this project required a great amount of guidance and co-ordination between the two organizations.

We would like to use this opportunity to pen down our profound gratitude and appreciations to **the Executive Engineer, Works Division III, Water Resources Department, Government of Goa f**or his guidance and extending all the required support from time to time, in all stages of the project.

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Advance Land & Hydrography Survey India Pvt. Ltd. P.O.-Bankra P.S.-Domjur Howrah 711403

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The Anjunem Dam is located on the Sanquelim-Belgaum highway in Chorla ghat at about 10 km from the Sanquelim town. It is one of the most idyllic places to enjoy the mystic charm and greenery around. The dam lies in a sylvan valley formed by the proximity of another peak, Morlemgad to its south-east and below one of Goa's highest peaks, Vagheri hill.

1.1 Work Order:-

Government of Goa
Office of the Executive Engineer
Works Division III
Water Resources Department
Ponda – Goa
4th Floor, Government Building, Tisk,Ponda, Goa 403401
Tel: 0832-2312093. Telefax: 0832-2312093. Email: ee3-wrd.goa@gov.in

No.89-2/WDIII/WRD/ACCTS/NHP/2019-20/03 Dated: 17/ 02 /2020

LETTER OF ACCEPTANCE
CUM NOTICE TO PROCEED WITH THE WORK

To:
Advance Land&Hydrography
Survey India Pvt.Ltd.
Vichitra SP-46,Kolkata West
International City,Salap Junction,
P.O-Bankra,P.S.- Domjur,
Howrah- West Bangal.
711403.
Email:advancesurveyindia@gmail.com

Name of work: National Hydrology Project-Hydrographic and Topographic Survey for Sedimentation survey of reservoirs of Salaulim Irrigation Project and Anjunem Irrigation Project in Goa.

Sir,

This is to notify you that your Bid dated 4th December 2019 for National Hydrology Project- Hydrographic and Topographic Survey for Sedimentation survey of reservoirs of Salaulim Irrigation Project and Anjunem Irrigation Project in Goa, for Contract Price of Rs.20,31,400.00 (Rupees twenty Lakhs thirty one thousand four hundred only)is hereby accepted by us.

P.O.-Bankra P.S.-Domjur Howrah 711403 Advance Land & Hydrography Survey India Pvt. Ltd. Vichitra SP-46, (KWIC)

You are hereby requested to furnish performance security for an amount of Rs. 1,01,570.00 (equivalent to 5 % of the contract price) within 15 days of the receipt of the letter. The Performance Security in the form of Bank guarantee in favour of The Executive Engineer, Works Division III, Water Resources Department, Ponda –Goa, shall be valid till 01-03-2021. Failure to furnish the Performance Security will entail cancellation of the award of contract.

You are also requested to sign the contract agreement form and proceed with the work not later than 2nd March 2020 under the instructions of the Engineer in-charge and ensure its completion within the contract period of 6 Months

With the issuance of this acceptance letter and you're furnishing the Performance Security, contract for the above said work stands concluded.

Date of commencement of work: 02-03-2020

Date of Completion of work: 28-08-2020

17/02/2020.

Executive Engineer.

For and on behalf of Governor of Goa.

Copy submitted to: -

1 The Chief Engineer, WRD, Sinchai Bhavan, Porvorim-Goa.
2)The Superintending Engineer, Circle III/IV/V,WRD,GogalMargao-Goa.
3) Office Copy
4) Guard file.

Copy to: -

1) The Executive Engineer WD V/X WRD Sankali/Sanguem
1) The Assistant Engineer, SD III, WD III, WRD, Gogal-Margao Goa, to give the site location to the Contractor.
2) The Income Tax Officer, Panaji-Goa.
3) The Deputy Commercial Tax Officer, Ponda ward, Ponda-Goa
4) The Labour Commissioner, Junta House, Panaji-Goa

Figure 1- Work Order

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1.2 Location:-

The Anjunem Irrigation Project is located on Costi nadi at Anjunem village in Sattari Taluka of North Goa District, a tributary of Valvanti River under Madei Basin. The dam is located between 15 36'57" to 15 33'30" latitude and 74 5'22" to 73 58'30" longitude.

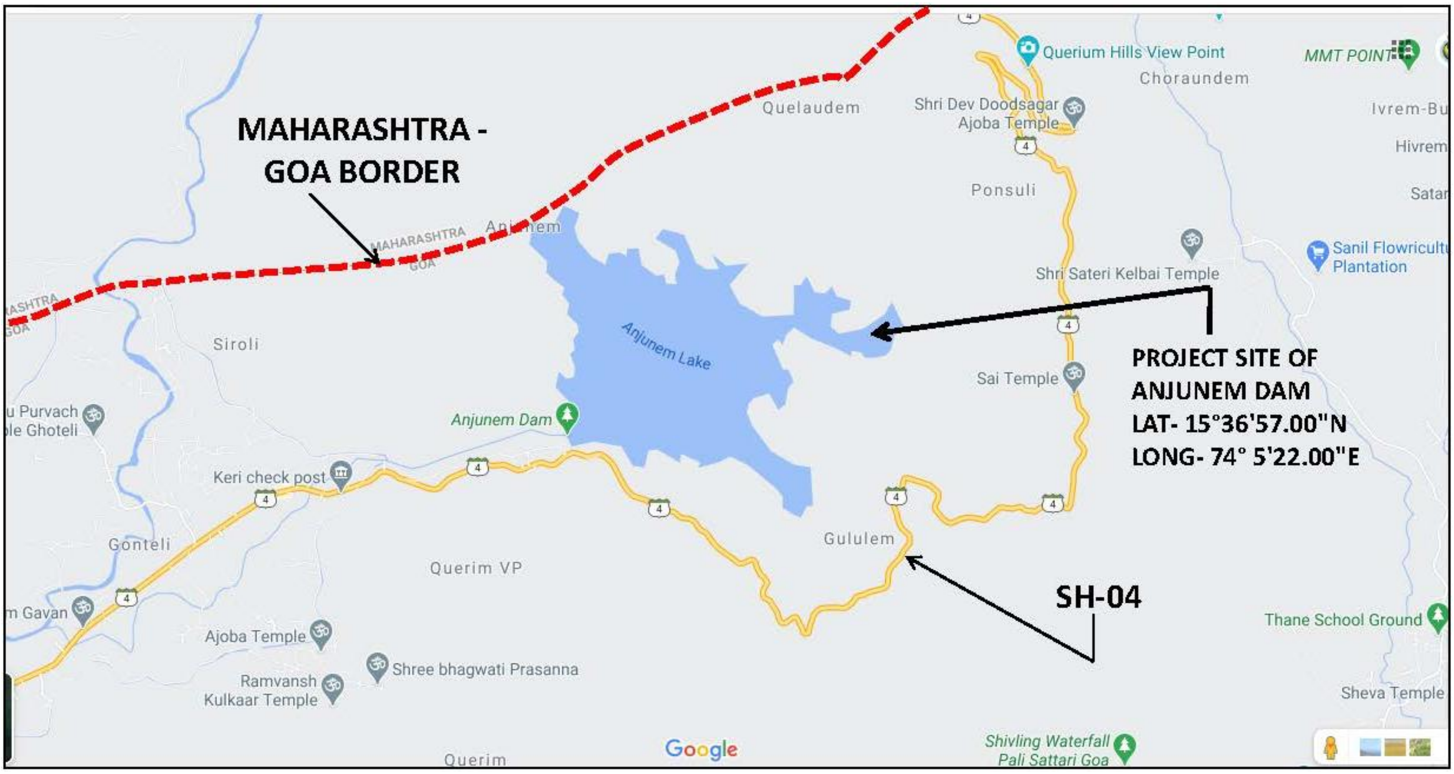

Figure 2- Location Map of Anjunem Dam

1.2.1 Purpose:-

The primary purposes of Anjunem Dam are Irrigation and water supplies are some of other important purposes.

1.3 Dam Description:-

The Type of Dam is straight Gravity Masonry dam with total length of 176.00m (577.28ft). The maximum height above the deepest bed level is 42.8 m. and the elevation of the top of the dam is 96.2 meter. The Dam has a dead storage level of 62.0 m and live storage level has 93.2 meter. The Maximum water level of the dam is 93.2 meter. The FRL of the dam is 93.2 meter. The length of the spillway is 39.48 m. The elevation of the spillway crest is 86.90 meter. The dam has a 4 no. of gates and the size of the gates is 7.62x 6.85meter.

1.4 Basin Description:-

The Dam is located on the Mandovi river basin. The nearest town is Mapusa. The Catchment area of the Dam is 17.18 km2. The Deepest bed level of the dam is 53.4 meter.

1.5 Hydrology:-

The Drainage area upto the Dam site is 17.18 km2 (6.63 Sq. miles). The Average monsoon rainfall is 3730mm (147 2"). The Maximum monsoon rainfall is 5358 mm (211 6"). The Minimum monsoon rainfall is 2369 mm (93.4"). The Maximum observed flood is 42.33 cum/Sec (01496 Cusec). The Maximum design flood is 17000 Cusecs and routed discharge is 17,000 Cusecs.

2.0 Description about Sedimentation:-

Dam sedimentation is the gradual accumulation of the incoming sediment load from a river. This accumulation is a serious problem in many parts of the world and has severe consequences for water management, flood control, and production of energy. The gradual process of sedimentation proceeds with different speeds that depend on a large number of factors, such as hydrology of the catchments and the characteristics of the river basin. Sediment will eventually fill a Dam within 50–200 years. Here, the crucial point is the fact that Dam sedimentation is just a symptom of erosion of the topsoil. The principal causes are anthropogenic activities such as deforestation, and overgrazing. The complexity of the problem increases when the anthropogenic activities interact with natural changes imposed by the dynamic nature of climate and the earth surface.

2.1 Causes of Sedimentation in a Dam:-

Trapping sediment behind a Dam not only causes sediment to accumulate in the Dam, but simultaneously results in a decreased sediment supply to the downstream river channel and a hungry water condition, which often results in downstream erosion of the stream bed and banks, and a coarser bed.

All rivers contain sediments a river, in effect, can be considered a body of flowing sediments as much as one of flowing water. When a river is stilled behind a Dam, the sediments it contains sink to the bottom of the Dam.

Trap efficiency can be defined as the ratio between the total sediment deposited in a Dam and the total sediment flowing in the river for a certain period. Therefore, Trap efficiency is:-

$$\frac{\text{Total Sediment deposited in the Dam}}{\text{Total Sediment Flowing in the River}}$$

– Known as its "trap efficiency" – approaches 100 per cent for many projects, especially those with large Dams. As the sediments accumulate in the Dam, so the Dam gradually loses its ability to store water for the purposes for which it was built. Every Dam loses storage to sedimentation although the rate at which this happens varies widely. Despite more than six decades of research, sedimentation is still probably the most serious technical problem faced by the Dam industry.

The rate of Dam sedimentation depends mainly on the size of a Dam relative to the amount of sediment flowing into it: a small Dam on an extremely muddy river will rapidly lose capacity; a large Dam on a very clear river may take centuries to lose an appreciable amount of storage. Apart from rapidly filling their Dams, sediment–filled rivers also cause headaches for Dam operators due to the abrasion of turbines and other Dam components. The efficiency of a turbine is largely dependent upon the hydraulic properties of its blades, just as an Aeroplane depends on the aerodynamic properties of its wings. The erosion and cracking of the tips of turbine blades by water–borne sand and silt considerably reduces their generating efficiency and can require expensive repairs.

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2.2 Description about N.H.P:-

NHP will improve and expand hydrology data and information systems, strengthen water resources operation and planning systems, and enhance institutional capacity for water resources management. The project will thus strengthen the information base and institutional capacity for evidence-based decision making in water resources planning and operational management at the basin scale across India using the latest technology and tools. NHP will contribute to the GOI Digital India initiative by integrating water resources information across state and central agencies.

NHP will span both states that benefitted from HP-I and HP-II investments and states that were not included in the earlier projects. In the new states, investments will be needed to move beyond existing basic infrastructure, following the approaches developed in the earlier projects. For HP-I and HP-II states, investment will focus on upgrading and completing networks. For all states, the focus will be on using the information generated for water planning and management.

The expectation is that knowledge, open access and stronger institutional capacity will contribute to a shift towards integrated water resources management at the basin scale. The resulting improved water allocation and use efficiency and the improved management of drought and flood risks are expected to bring substantial socio-economic benefits.

2.3 Survey by Advance land & Hydrography Survey India Pvt. Ltd.:-

Advance land & Hydrography Survey India Pvt. Ltd. conducted **"Sedimentation Survey Report of Anjunem Dam under NHP" No-WDIII/WRD/ACCTS/NHP/2019-20/03 Dated- 17.02.2020**

2.4 Weather:-

The survey was undertaken during the month of 'February 06th to 9th, 2021'. The Temperatures became average for the Sedimentation Survey of Anjunem Dam.

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3.0 Project Site Location Map of Anjunem Dam:-

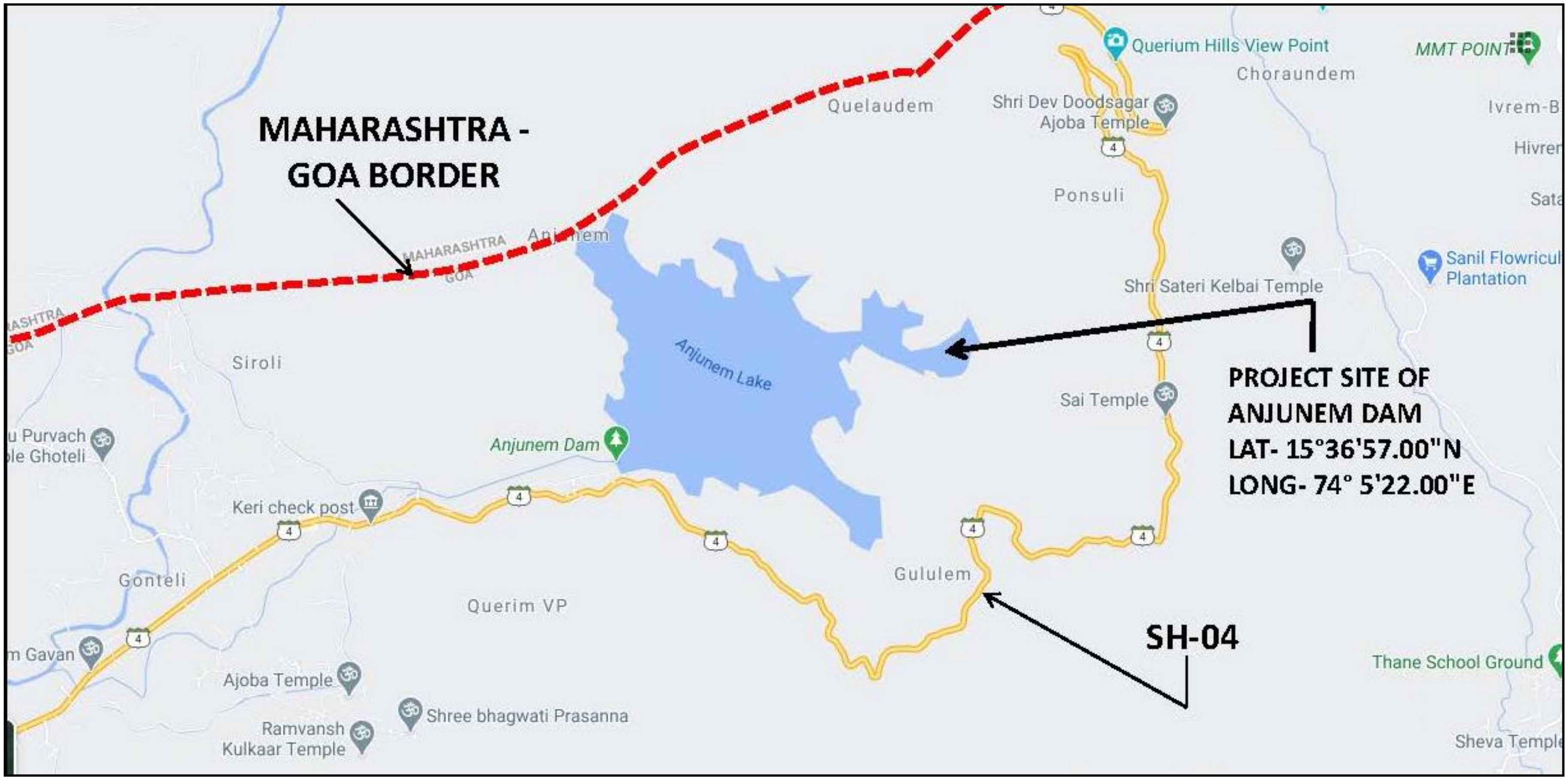

Figure 3-Project site location Map of Anjunem Dam

4.0 Scope of Work:-

The scope of the work includes:-

Brief Description of the work	Intended Completion period
Sedimentation Survey Report of Anjunem Dam under NHP No-WDIII/WRD/ACCTS/NHP/2019-20/03 Dated - 17.02.2020	

The Objective of Sedimentation survey is in the following:-

A. Request of Proposal:-

a. Mobilization of Personnel, equipments, instruments, establishment of site camp etc.

b. Lay out of Ground control stations including reconnaissance/Preliminary Surveys, if any.

c. Conduct Hydrographic and Topographic Survey to cover the entire area of the Dam up to maximum water level (100 m x 100 m grid for hydrographic survey and 100 m x 100 m grid for topographic survey). For small Dams (water spread area less than 30 sq.km.), grid of 50 m x 50 m shall be adopted for both hydrographic and topographic survey.

d. Collection and analysis of sediment samples from the Dam bed with not less than 10 samples covering the entire area of the Dam. Location of the collection points should be clearly indicated on a map.

e. Collection of information from project authorities/any other agency including data on sediment yield from the upstream free catchment of the Dam as well as accounting for the effect of upstream Dams, if any and incorporating of the same while writing the report.

f. Analysis of data to obtain elevation-area-capacity table/curves, contour plots, balance life of Dam, cross sections, L-sections, vertical sediment distribution curve/table, estimation of sedimentation in different zones of Dams, mathematical modeling studies etc. keeping in line with the objectives laid down for the study.

g. Preparation of Report containing general information about the Dam, catchment characteristics, details of capacity survey performed including methodology of data collected, analysis of data with standard guidelines/Procedures, finding of results, conclusion and recommendations keeping in view the objective of the study to the satisfaction of water Resources Dept., Goa.

h. Any difficulties/special problem encountered during the course of the study and how they were overcome may be included in the report.

i. The work shall be completed by the agency in twelve months time with effect from 21 days after the agreement has been signed.

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B. Equipments Preferred :-

High-technology equipments like integrated Hydrographic Survey System which should include recording type echo sounder and computer software for interfacing and recording the position and depth data in real time. GPS Survey technology is essential.

C. Capacity Survey:-

a) Hydrographic Survey

Computer based Hydrographic survey shall be carried out within the water spread area so that Dam area under water is covered at 100 m x 100 m grid. For small Dams (water spread area less than 30 Sq.km.), grid of 50 m x 50 m shall be adopted.

b) Topographic Survey

The Area not covered under Hydrographic Survey up to MWL shall be surveyed by taking levels at 100 m. interval along range lines laid at 100 m interval. (100 m x 100 m grid). For small Dams (water spread area less than 30 sq.km.), grid of 50 m x 50 m shall be adopted.)

c) Collection of bed materials samples

Not less than 10 samples of the bed material shall be collected as per standard methods prescribed in APHA 1989 (American public health Association) covering the entire area of the Dam to obtain sediment sizes, density, specific gravity, moisture content etc. Depth and location of sample collection are to be mentioned.

D. Data Analysis/Preparation of Tables/Charts/Drawings:-

After Completion of the capacity survey, the survey data shall be analyzed by the consultant to obtain the following:-

i) Elevation-Area-Capacity Curves as well as table

Elevation–Area-Capacity curve along with table will be prepared from the lowest elevation up to MWL at 1.0 m or less interval.

ii) Assessment of effects of sedimentation on performance of Dam and balance life of Dam

Assessment of sediment and its distribution in the Dam shall be made and likely effects of such sedimentation on the performance of the Dam shall be assessed. While analyzing the Dam data, the validity of Empirical area reduction method using data of silt deposition collected during survey may also be checked out. The Elevation-Area-Capacity curve and L-Section may be produced for another 100 years at 10 years interval by conducting mathematical modeling studies. The Consultant may refer to various standards/references including I.S. 12182-1987 "Guidelines for determination of effects of sedimentation in Planning and Performance of Dam", C.B.I & P publication on the subject and I.S. 5477 Part-II "Fixing capacities of Dams-Dead storage".

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Separate Chapters are to be included in the report for "Sedimentation Analysis", "Life of Dam", "Mathematical modeling", "Soil Conservation Measures "and "Conclusions and Recommendations".

A sample calculation is to be shown for each: Estimation of rate of sedimentation, expected life of Dam, prediction of sediment distribution etc. Future sediment calculations shall be based on every 10 years block.

iii) Estimation of sedimentation in different zones of Dam

Loss of storage capacity and rate of sedimentation shall be worked out in each vertical zone separately viz. dead storage, live storage and flood storage, if any. An assessment of the sedimentation behaviors' in different horizontal zones throughout the Dams may also be made.

iv) Analysis of Bed material samples

Laboratory analysis of the bed material samples collected from the Dam bed be carried out to obtain sediment sizes, density, specific gravity, moisture content etc. Analysis of samples should also be aimed to evaluate geometric standard deviation to know whether the sediment is uniform or non uniform (Melville et al.). Kramer's coefficient shall also be evaluated. Method of calculation of bulk density (Lane's method or miller's method or some other method) is to be mentioned.

v) Cross sections

Cross sections showing the original bed profile, if available and subsequent repeat surveys at every 1 km shall be provided. Raw data of cross sections at every survey line (100 m interval) shall be provided as soft copy in CD to **the Executive Engineer, Works Division III, Water Resources Department, Ponda, Goa**.

vi) L-section

L-Section of the Dams may be prepared with the lowest bed levels at every survey line.

vii) Vertical sediment Distribution

Vertical sediment distribution curve/table shall be provided. Plot between percent Dam depth and percent sediment deposited is to be plotted as per IS 5477 PART-II 1994. "Fixing capacities of Dams-Dead storage".

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viii) Contour map of the Dam

The Contour map shall be prepared in appropriate size preferably in A0 size with contour at suitable interval from the lowest bed level to MWL (Maximum water level).

ix) Trap Efficiency of Dam

The trap efficiency of Dam is to be calculated according to Brune's trap efficiency curve as per I.S 12182-1987 "Guidelines for determination of Effects of Sedimentation in planning and performance of Dams".

x) Charts/drawings for the Report

All charts/drawings shall be appropriately reduced for inclusion in the report.

The entire data observed during hydrographic survey by the consultant and the subsequent report prepared by him shall be the exclusive property of **Water Resources Department** and the consultant has no right whatsoever to divulge the information/data to others without the specific written permission of **Water Resources Department.**

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5.0 Authentic Reference level:-

For the Topographic / Hydrography Survey, the Level has been carried out from the **GTS Pillar near Anjunem Dam** which is tabulated below:-

Location	BM/CP	Easting (m)	Northing (m)	Latitude (N)	Longitude (E)	Elevation (m)
Anjunem Dam	GTS Pillar	402339.021	1726671.414	15°12'32.64"	74°10'32.63"	97.740

Figure 4- Authentic reference level of Anjunem Dam

6.0 Conduct of survey work

6.1 Topographical Survey with RTK:-

The Topographic survey was conducted to ascertain following in the survey area:-

- Spot levels
- High bank Line
- Low Bank Line
- Fixing of bridges / cross structure and marks
- Collection of local information along the river Banks

The spot levels/Topographical Survey along the Anjunem Dam was obtained by using GPS/RTK technique. Local terrain and limitation of line of sight visibility prohibited the use of optical techniques for obtaining spot levels. In the GPS/RTK spot leveling technique being used, the GPS /RTK control was extended using the co-ordinates and height of the recovered geodetic station established to various BM in the respective stretches. These BM were then used as reference stations for deriving the spot levels of the rover locations in the Stop-Go method. The details of all spot levels are provided in the respective sheets being presented along-with this report. Additionally, a soft copy of the same in XYZ format is being handed over as deliverable data.

- **Projection** - **UTM (*Universal Transverse Mercator coordinate system)***
- **Spheroid** - **WGS 84**
- **Vertical Datum** - **M.S.L**
- **Grid** - **UTM North (43 N)**
- **Scale factor** - **As per requirement**

Figure 5- During Topographical Survey with RTK

7.0 Data Processing:-

The Topographic data collected during the field work was processed and analyzed using the proprietary data processing software. The following flow chart explains the sequence and process of digital data processing:-

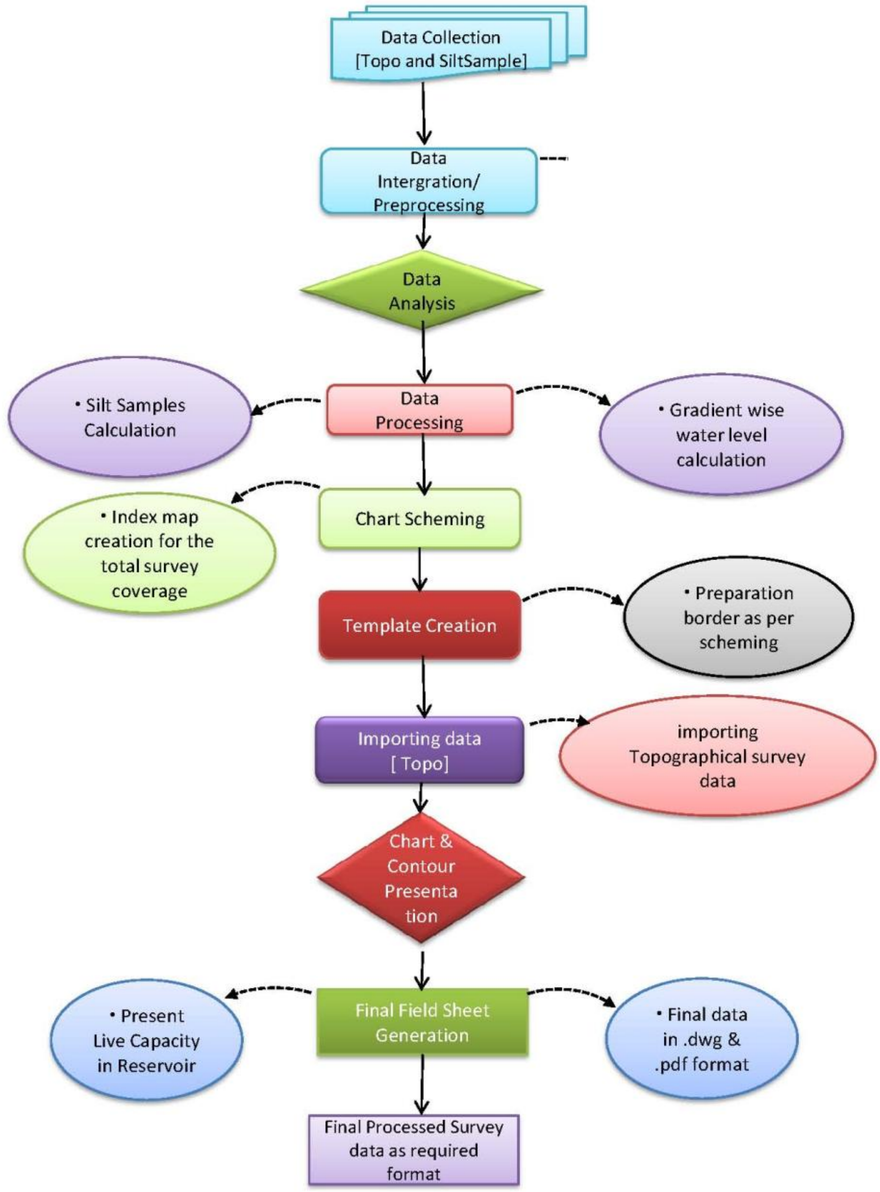


Table 1-Data Processing

8.0 Hydrography Survey with Echotrac E-20:-

TELEDYNE ODOM HYDROGRAPHIC

SBES User Interface

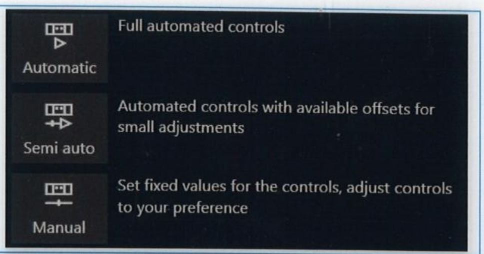
Singlebeam Echosounders - Quick Start Guide

Operation Setup

- Select your desired operation mode.

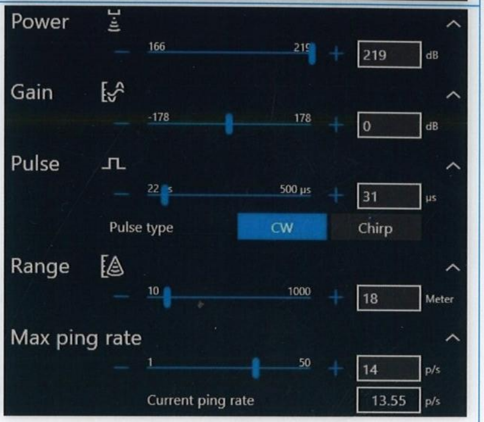
  Automatic is the recommended mode for most operators. Manual is for the experienced operator.

  The Semi auto and Manual modes gives you partial or full control of the system.



Basics for Manual Mode

- Depending on water depth and bottom type, set the Power to mid-range.
- To start with, leave Gain at its halfway setting. Adjust the setting later based on a review of the echogram data.
- Set a Pulse length appropriate for the working water depth. In general, a short pulse performs best in shallow water and a longer pulse performs best in deeper water.
- Set Range to just beyond the anticipated maximum water depth.
- Set Max ping rate. The unit's achievable ping rate is affected by the sonar settings and transducer characteristics, but most directly by the range setting. As the range increases, so does the two-way travel time for the sent signal. Therefore, the current ping rate is displayed in the information box.
- Adjust Power and Gain to get a clear strong record.



Note: Help visualize and quality assure the echosounder performance by changing the echogram color palette, brightness, and contrast.

Echogram Settings

- Click the Echogram tab.
- Make your choice in the Color palette drop-down menu and/or click the Invert color button to fit your display preferences.
- Adjust brightness and contrast manually – or click the Automatic button to let the system control the settings.
- Range mode echogram display options:
  - Automatic –includes the option of toggling Center on Digitized Depth on/off
  - Fixed range – includes a field for entering a value
  - Follow range
- Select either the Marking or Spike style for visualizing the depth line, when the E20 measures an invalid depth.

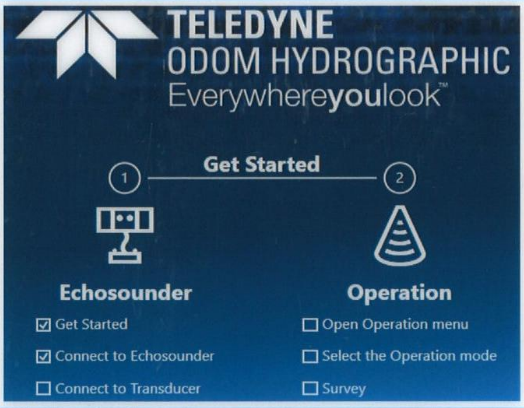
Settings

- Click the Settings tab.
- Toggle Night view on/off.
- Recording location (s7k, snapshot & video):
  - Define a storage folder.
  - Define a file prefix for snapshots and videos.
- Revert to default SBES UI settings by clicking the Restore button.

TELEDYNE ODOM HYDROGRAPHIC

SBES User Interface

Singlebeam Echosounders - Quick Start Guide



SBES User Interface

The SBES User Interface is designed to operate with minimal operator input while maintaining complete flexibility for a wide range of conditions and applications.

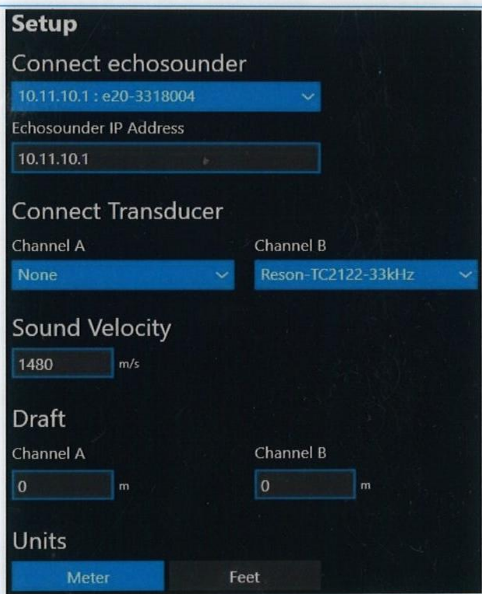
This Quick Start Guide provides you with the recommended settings for the most basic sonar control parameters.

The SBES UI will guide you through the necessary steps to get ready for operation.

As environmental conditions vary, it is not possible to cover every scenario. The settings here apply to typical operations.

Echosounder Setup

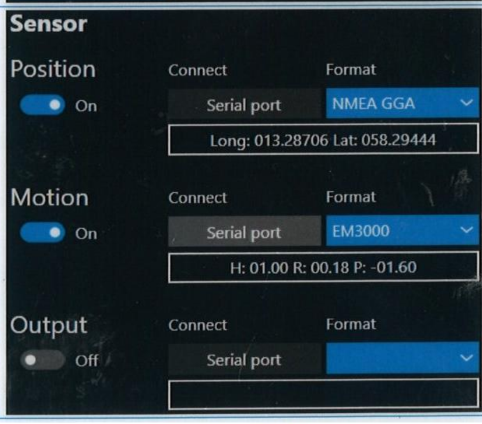
- Click the Echosounder tab.
- Select the IP address with the serial no. of your E20 system in the Connect echosounder drop-down menu. (The serial no. is on the front of the E20.)
- Select the correct transducer type from either the Channel A or Channel B drop-down menu. For the current single channel operation, the selection for the other channel should always be None.
- Enter a sound velocity applicable for the survey area.
- Enter the transducer draft from the vessel waterline. The draft is added to the depth measured by the E20.
- Select your preferred unit choice of Meter or Feet. The unit setting is universally applied within the SBES UI.



Sensor Setup

- Click the Sensor tab.
- For each sensor, select the format of your data via the Format drop-down menu.
- Click the Serial port button to configure the port to match the settings of the sensor output.
- Toggle the Position and/or Motion input on/off. You will see the data updating in the preview window for each sensor.

  Note: When Motion input is on, only the Heave field is used by the E20 to correct measured depths.



8.1 Explanation Regarding the Methodology of Survey Work:-

1. Firstly we engaged a boat to survey the project site with equipped machineries.
2. We deployed Real Time Kinematics (RTK) with 20mm vertically & 10mm horizontally capability.
3. RTK had been shown the X & Y value.
4. In addition with this we engaged Echo-Sounder to calculate the depth. **Echotrac E-20 Echo-Sounder** was used to obtain soundings on board the survey launches. A working frequency of 200 KHz was used for sounding operations. The digital output from the echo sounder was fed to the navigation data logging software for acquisition of survey data in real time. The performance of the echo sounder was found to be satisfactory during the entire duration of the survey.
5. We kept Power navigation software to interface RTK & ECHO Sounder.
6. Hypack navigation software helped to show the final date at the surveyed area.
7. Verification of water level in the Dam have constantly been monitored (manually from outside Dam) during hydrographic survey which have been used in operating Echo-sounder for measuring depth correctly.
8. Thus finally we got the result i.e. water level – depth.

Figure 6 - During the Hydrography Survey in Anjunem Dam

P.O.-Bankra P.S.-Domjur Howrah 711403

8.2 Hydrography Survey Process :-

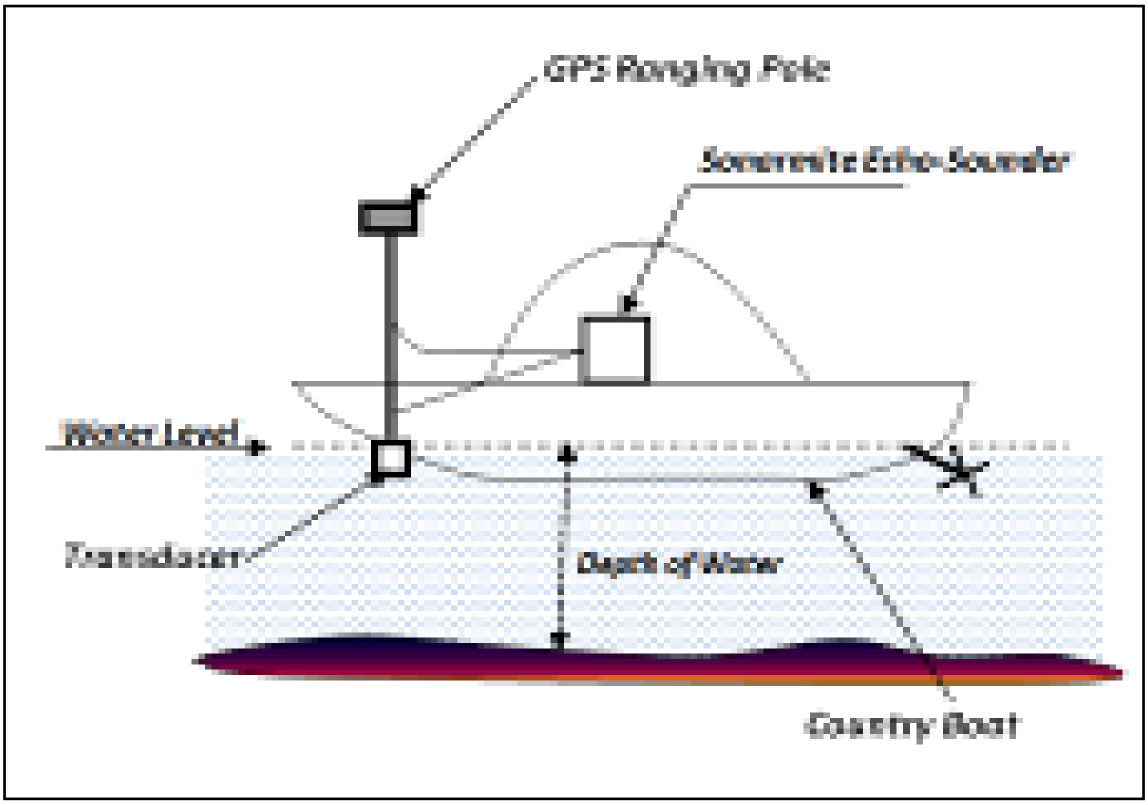


Figure 7 - Schematic diagram showing the sequence of operation

8.3 Hypack Data Processing System:-

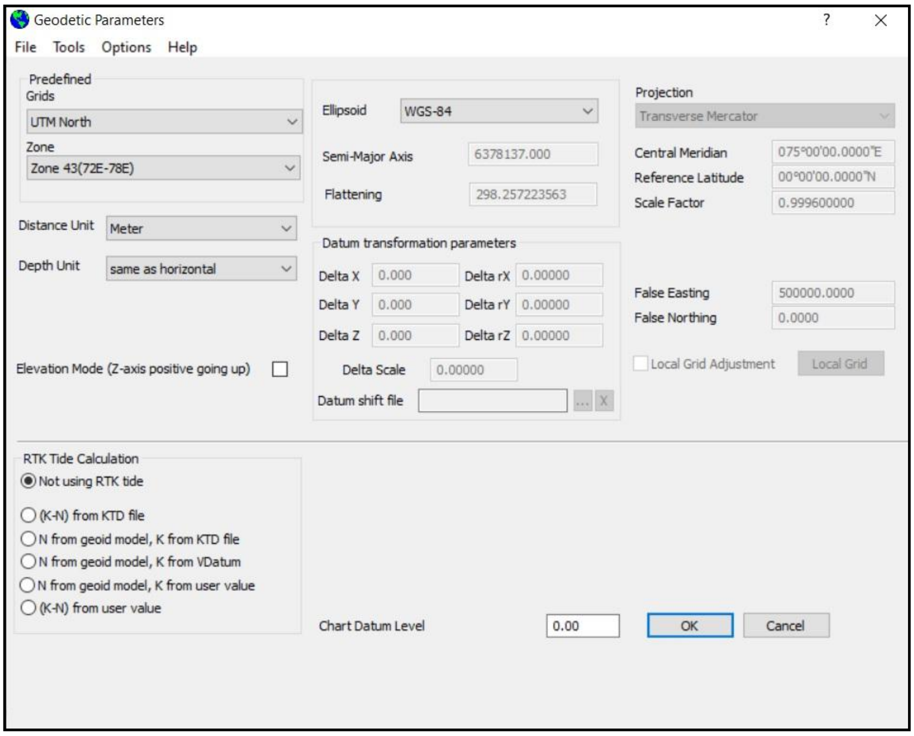


Figure 8-Hypack Data Logging, Geodetic Parameters

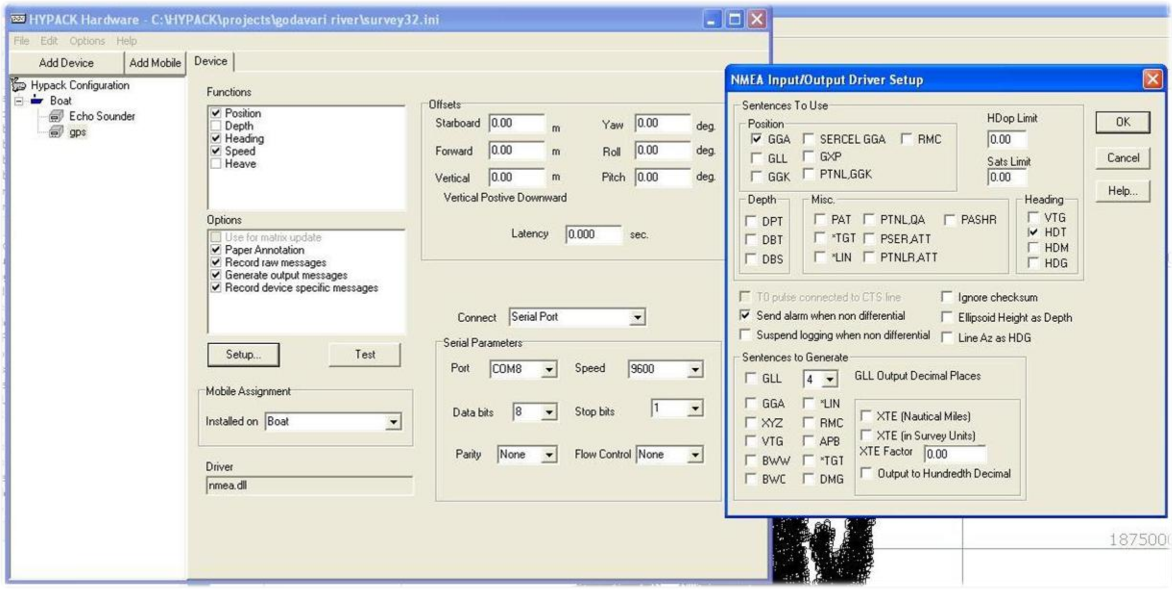


Figure 9 - Hypack Data logging, Navigation I/P settings

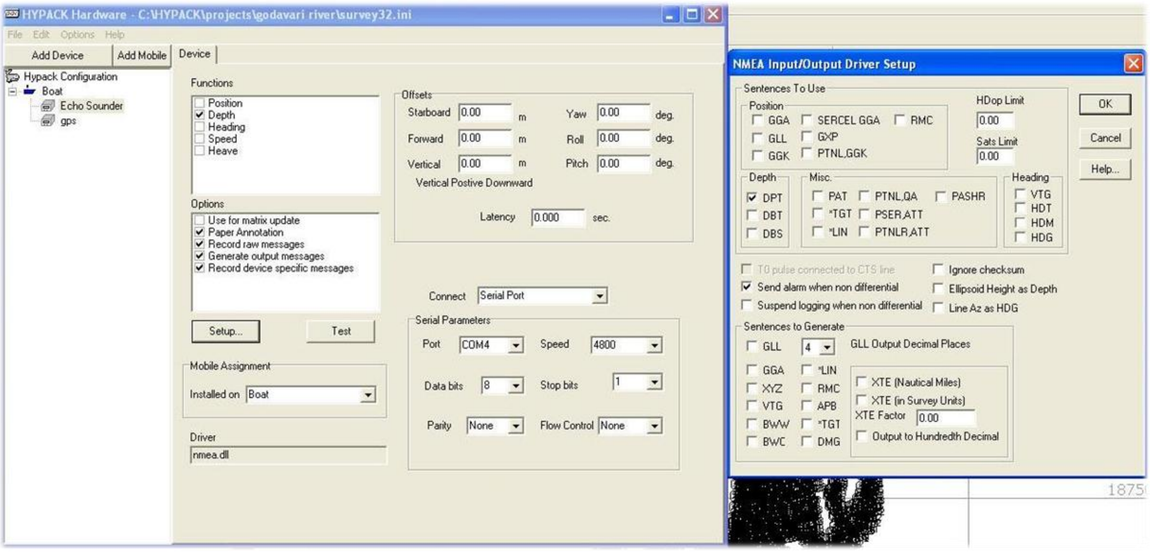


Figure 10 - Hypack Data Logging, Echo-sounder I/P settings

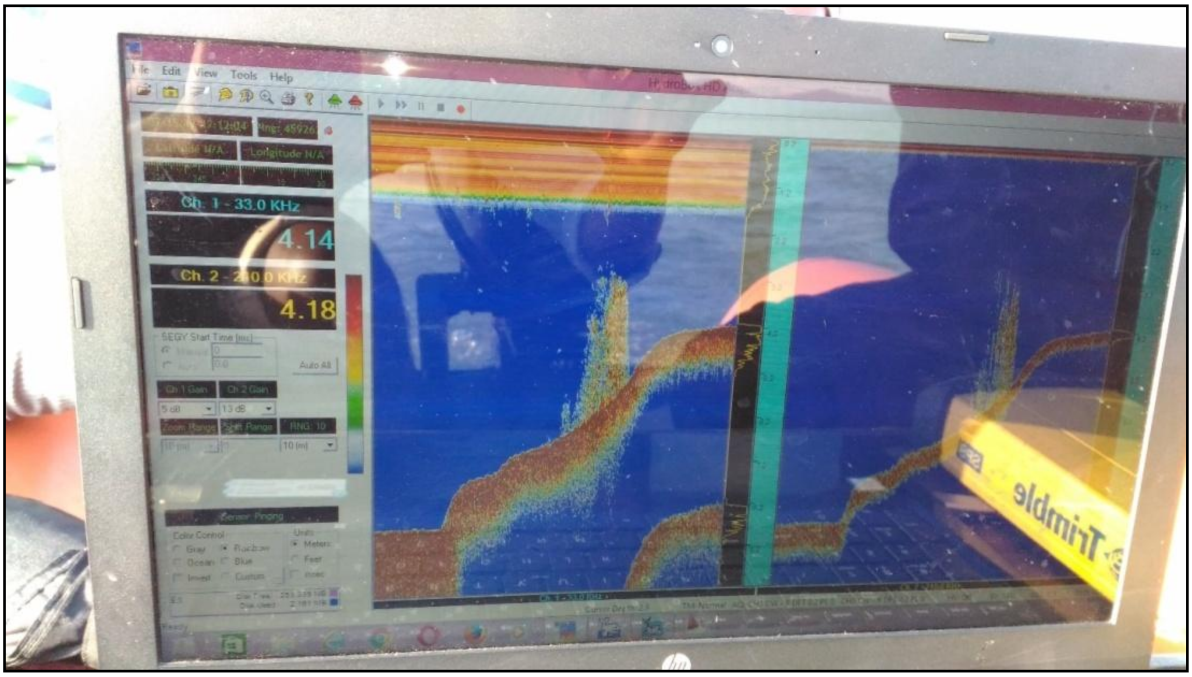


Figure 11-Hypack data processing

9.0 Soil and Water Sample Position:-

The Soil and water samples (10 no's) are collected from various locations near Anjunem Dam which are tabulated below. The location maps of soil samples are also indicate in the next pages (page no-26) with the same Coordinate.

Anjunem Soil & Water Sample locations				
Sl. No	Easting (m)	Northing (m)	Latitude (N)	Longitude (E)
1	402442.98	1726821.8	15°37'2.58"	74° 5'23.73"
2	402451.76	1727481.51	15°37'24.05"	74° 5'23.93"
3	402333.71	1727869.82	15°37'36.67"	74° 5'19.91"
4	402867.57	1727434.87	15°37'22.59"	74° 5'37.90"
5	403469.54	1727469.8	15°37'23.81"	74° 5'58.11"
6	404336.24	1727361.06	15°37'20.39"	74° 6'27.23"
7	403275.57	1727022.29	15°37'9.22"	74° 5'51.66"
8	403007.58	1726678.34	15°36'57.99"	74° 5'42.71"
9	403338.47	1726756.83	15°37'0.59"	74° 5'53.81"
10	403761.74	1726428.09	15°36'49.95"	74° 6'8.07"

Table 2 – Soil and water sample positions

9.1 Google image of Soil Sample locations:-

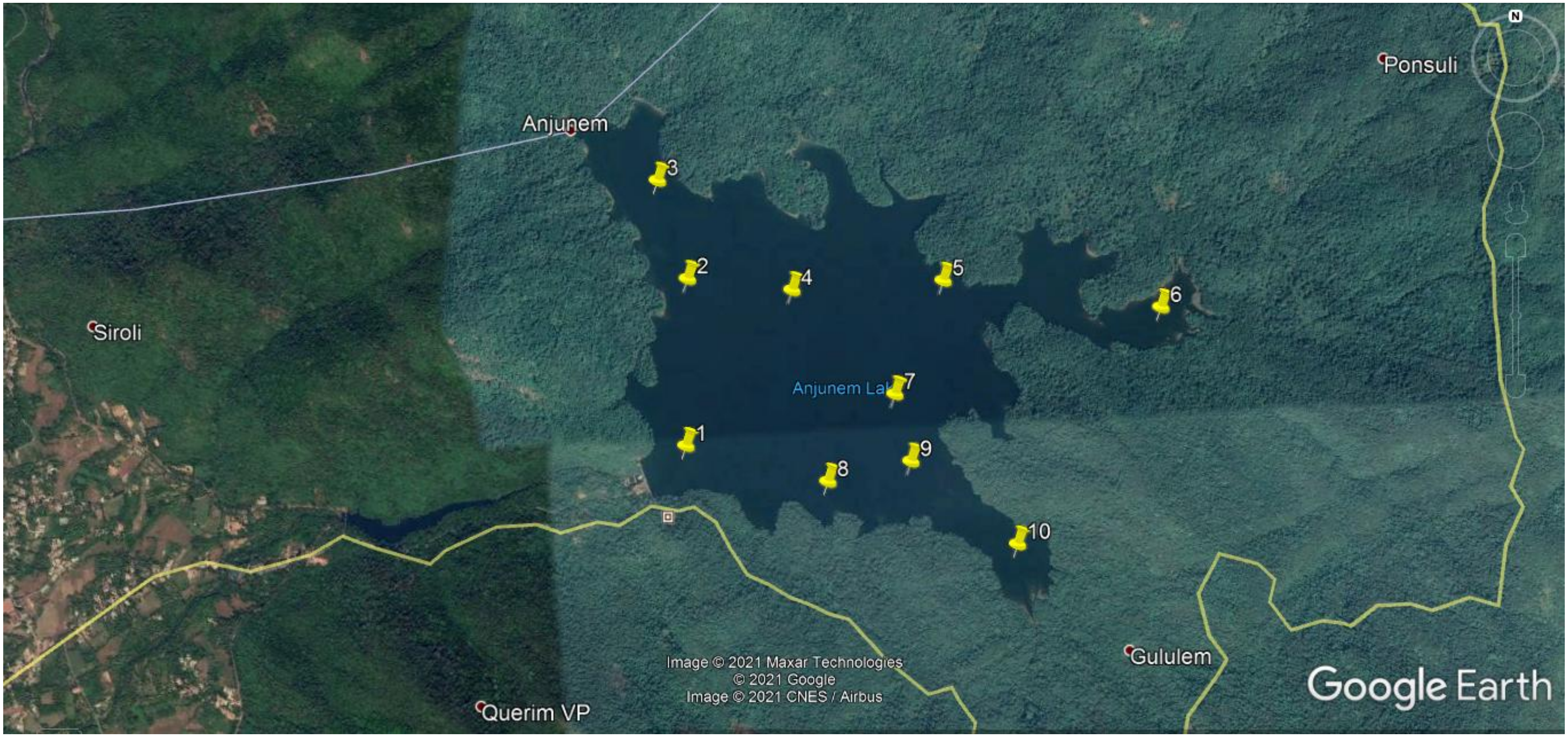


Figure 12-Soil sample locations

10.0 Salient Features of Anjunem Dam:-

Salient Features of Anjunem Dam		
Location	State	Goa
	Taluka	Sattari
	River	Gulleli (Costi Nadi)
	Latitude	15°36'57"
	Longitude	74°05'22"
Dam	Catchment Area	17.18 KM^2
	Deepest Bed Level	R.L 53.4m
	Dead storage Level	R.L 62.0m
	Maximum water Level	R.L 93.2m
	Capacity D.S.L	80.00 ha.m
	Capacity at F.R.L	4483 nha.m
	Area of Submergence at F.R.L	253 ha (623 Acres)
Dam	Type of Dam	Straight Gravity Masonry dam
	Total Length of Dam	176.00m
	Maximum height above the deepest bed level	42.8m
	Top of Dam	R.L 96.2m
Spillway	Length of Spillway	39.48m
	Elevation of Spillway Crest	86.90m
	Type of Crest Gates	Radial
	Size of Gates	7.62 x 6.85m
	No of Gates	4 no
Irrigation	Gross Command area	2624 ha
	Irrigation area	2100 ha
Length of Main Canals	Right Bank	21.90 km
	Left Bank	7.73 km
Submergence Details	Area Submerged	253 ha
	Number of Village Submerged	4 nos
	Number of Affected Families	344

Table 3- Salient features of Anjunem Dam

11.0 Survey Equipments:-

SERIAL NO.	EQUIPMENT NAME	MODEL NO.
1	ECHO SOUNDER	ECHOTRAC E-20 (TELEDYNE)
2	BEACON RECEIVER (RTX)	SPECTRA PRECISION SP-60
3	DGPS	TRIMBLE SPS-986
5	SOIL SAMPLE & WATER SAMPLE	VANVEEN GRAB & BOTTLE SAMPLER
6	HYPACK NAVIGATION SOFTWARE	VERSION-19
7	AUTOCAD/CIVIL 3D	2015
8	MICROSOFT OFFICE	2015

Table 4- Details of equipment lists

- Survey Boat/Vessel:- 1 no Survey Vessel with Yamaha 9.9 stroke engine:-

Figure 13- DGPS Survey Instrument

- Positioning System:-

- 1 no RTX Spectra Precision DGPS system (SP-60)

- Navigation & Data Logging System:-

- To provide on-line route guidance, log navigation data, provide QC of navigation data, etc. The system comprises the following equipment :-
- 1 no. DELL Laptop
- 1 no. Hypack version 2019 Navigation & Data Logging Software
- 1 no. Positioning & sensor interfaces
- Sufficient Paper Rolls

- Single Beam Echo Sounder System:-

  - 1 no. Echotrac E-20 Single frequency dual Channel Echo sounder
  - 1 no. transducer 200 kHz + mounting bracket & base plate

Figure 14- Echo Sounder Instrument (E-20)

- 1no DGPS (Trimble SPS-986):-

- 1no Soil (Van veen grab) & water (Bottle Sampler) :-

12. Calibration:-

The equipment used for the survey was calibrated by the equipment supplier. The equipment calibration certificates are placed here to:-

12.1 Echo-Sounder Calibration:-

CERTIFICATE OF CONFORMITY

TELEDYNE MARINE
Everywhereyoulook™

FROM: Teledyne RESON A/S
Fabriksvangen 13
DK-3550 Slangerup

TO: ASB Systems Pvt. Ltd
203A, VIP Plaza, Off NewLink Road
Andheri (West)
Mumbai, 400053
INDIA

C.O.C. NO: OPP-5041
ORDER REFERENCE: OPP-5041
GOVERNMENT CONTRACT NO:
SHIPMENT NUMBER ON ORDER: 96215
PARTIAL: FINAL: X

ITEM NO	STOCK/PART NO: AND NAME	QUANTITY	UNDELIVERED BALANCE
SMBB200-9	Transducer, 200 kHz 9 degree.,Stainless steel, stem mount (SS510-2 housing), single frequency. 10m cable Serial: 60211354	1	0
88090305	SYS, ECHOTRAC E20, Dual Channel Serial: 4019021	1	0

Teledyne RESON reference hydrophones used in final testing and inspection have been calibrated by National Physical Laboratory UK (NPL) and NPL fulfills the requirements in ISO 10012 and ISO/IEC 17025.

The deliveries detailed above conform in all respects to the specification(s), drawing(s) and the related contract / order. The deliveries have been inspected / tested in accordance with the conditions and requirements of the contract / order. Where this does not apply, Teledyne RESON standards have been used.

DATE: 24.02.2020
SIGNATURE (SUPPLIER): Teledyne RESON A/S, Fabriksvangen 13, DK-3550 Slangerup
NAME (PRINTED): JANE RASMUSSEN

This is to certify that within the provisions of STANAG 4107 the deliveries detailed above have been subject to Government Quality Assurance and are considered to conform to the provisions of the applicable contract.

NATIONAL QUALITY ASSURANCE SERVICE (DELEGATEE): **N/A**
SIGNATURE:
DATE:
NAME (PRINTED):

Teledyne RESON A/S Quality Management System Fulfils the requirements of ISO9001:2015. The certificate has been issued by DNV GL – Business Assurance A/S, Denmark. And is the property of DNV GL.

Figure 15- Calibration Certificate of Echo-Sounder (E-20)

Advance Land & Hydrography Survey India Pvt. Ltd., P.O.-Bankra, P.S.-Domjur, Howrah 711403

12.2 Trimble SPS-986:-

PAN INDIA CONSULTANTS PVT. LTD.

SALES DEPARTMENT

CORPORATE ADDRESS : 105, PHASE IV, UDYOG VIHAR, GURGAON-122015, HARYANA, INDIA
PHONES : +91 124 4300950, 4013954, FAX : +91 124 2346646, 2342880, CIN - U74899DL1985PTC021177
e-mail : paie@panindiagroup.com, paie@vsnl.com, www.panindiagroup.com

CALIBRATION CERTIFICATE

CUSTOMER NAME	:	ADVANCE LAND & HYDROGRAPHY SURVEY INDIA PVT LTD.
ADDRESS	:	P.O. –SALAP, P.S.-Vichitra SP-45,KWIC NH-6, Dist. –Howrah Pin: 711 403 W.B
INSTRUMENT	:	GNSS RECEIVER
SERIES	:	SPS 986
SERIAL NO.	:	5831F00023
CALIBRATION DATE	:	17/04/2020
VALIDITY	:	16/04/2021

THIS IS TO CERTIFY THAT THE ABOVE INSTRUMENT WAS CHECKED AND CALIBRATED IN ACCORDANCE WITH THE APPLICABLE FACTORY PROCEDURES.

for PAN INDIA CONSULTANTS PVT. LTD.

Pan India Consultants Pvt. Ltd. Gurgaon

AUTHORISED SIGNATORY

REGD. OFFICE : OFFICE NO. 1, D-4, COMMERCIAL AREA, VASANT KUNJ, NEW DELHI-110070, INDIA
PHONES : +91 11 26137657, 26137659, 26899952, 26899962, 26132214 FAX : +91 11 26138633
e-mail : nmspl@panindiagroup.com URL : www.panindiagroup.com

Figure 16- Calibration Certificate of SPS-986

12.3 Calibration Certificate of SP-60 (Beacon Receiver):-

PAN INDIA CONSULTANTS PVT. LTD.

SALES DEPARTMENT

CORPORATE ADDRESS : 105, PHASE IV, UDYOG VIHAR, GURGAON-122015, HARYANA, INDIA
PHONES : +91 124 4300950, 4013954, FAX : +91 124 2346646, 2342880, CIN - U74899DL1985PTC021177
e-mail : paie@panindiagroup.com, paie@vsnl.com, www.panindiagroup.com

CALIBRATION CERTIFICATE

CUSTOMER NAME	:	ADVANCE LAND & HYDROGRAPHY SURVEY INDIA PVT LTD.
ADDRESS	:	Vichitra SP-45, KWIC Bankra, P.S.- Domjur, Dist. –Howrah, Pin: 711 403 (W.B)
INSTRUMENT	:	Beacon Receiver
SERIES	:	SP60 (Spectra Precision)
SERIAL NUMBER	:	5528550001
CALIBRATION DATE	:	05/06/2020
VALIDITY	:	04/06/2021

THIS IS TO CERTIFY THAT THE ABOVE INSTRUMENT WAS CHECKED AND CALIBRATED IN ACCORDANCE WITH THE APPLICABLE FACTORY PROCEDURES.

For **PAN INDIA CONSULTANTS PVT. LTD.**

Srivastava

AUTHORISED SIGNATORY

REGD. OFFICE : OFFICE NO. 1, D-4, COMMERCIAL AREA, VASANT KUNJ, NEW DELHI-110070, INDIA
PHONES : +91 11 26137657, 26137659, 26899952, 26899962, 26132214 FAX : +91 11 26138633
e-mail : nmspl@panindiagroup.com URL : www.panindiagroup.com

Figure 17-Calibration Certificate of SP-60

Advance Land & Hydrography Survey India Pvt. Ltd. P.O.-Bankra P.S.-Domjur Howrah 711 403 Vichitra SP-46, (KWIC)

DATA ANALYSIS/PREPARATION OF TABLES/CHARTS/DRAWINGS

ELEVATION AREA CAPACITY CURVE AS WELL AS TABLE (i)

This Section has been analyzed the Elevation area capacity curve along with table which has been prepared from the lowest elevation up to MWL at 0.3 m interval.

13.0 Detail Analysis of Area Capacity Curve in the year 2021:-

13.1 Elevation Area Capacity curves as well as table:-

The Capacity Curve formula and Curve (Capacity Graph) has been shown respectively tabulated below:-

The Elevation area capacity table has been computed by the **Average end area formula**; that is equal to -

$h/2\ (A_1+A_2) = V$ (as per I.S. 5477 part-II-1994**)**

Where

h= the height of the segment (Contour interval)

A_1 and A_2= the contour area at the end of the segment and

V= the volume of the segment (Volume between two consecutive contour)

I.S. 5477 part-II-1994

computed by the average end area formula, that is equal to:

$$\frac{h}{2}(A_1 + A_2) = V \qquad \text{...... (6)}$$

where

h = the height of the segment,

A_1 and A_2 = the areas at the end of the segment, and

V = the volume of the segment.

P.O.-Bankra P.S.-Domjur Howrah 711 403 Advance Land & Hydrography Survey India Pvt. Ltd.

Anjunem Dam_ Detail Analysis for Elevation And Area Capacity Table 2021						
SL. NO.	**Contour EL (m)**	**Contour Interval (m)**	**Area**		**Capacity**	
			in Sqm.	***in Hectare***	***Vol. between two consecutive contour surface (in Cum.)***	**Cumulative Vol. *(in M-Cum.)***
1	56.0	0.00	602.77	0.060	0.000	0.00
2	56.3	0.30	1400.56	0.140	300.500	0.00
3	56.6	0.30	2015.54	0.202	512.416	0.00
4	56.9	0.30	2637.96	0.264	698.026	0.00
5	57.0	0.10	2902.28	0.290	277.012	0.00
6	57.2	0.20	3679.96	0.368	658.224	0.00
7	57.5	0.30	5129.75	0.513	1321.456	0.00
8	57.8	0.30	6738.72	0.674	1780.269	0.01
9	58.0	0.20	8112.39	0.811	1485.111	0.01
10	58.1	0.10	9014.74	0.901	856.357	0.01
11	58.4	0.30	11825.23	1.183	3125.995	0.01
12	58.7	0.30	15150.20	1.515	4046.314	0.02
13	59.0	0.30	18700.14	1.870	5077.551	0.02
14	59.3	0.30	23398.55	2.340	6314.803	0.03
15	59.6	0.30	26998.18	2.700	7559.508	0.03
16	59.9	0.30	34754.70	3.475	9262.931	0.04
17	60.0	0.10	38721.99	3.872	3673.834	0.05
18	60.2	0.20	44708.27	4.471	8343.026	0.06
19	60.5	0.30	52819.01	5.282	14629.091	0.07
20	60.8	0.30	59338.41	5.934	16823.613	0.09
21	61.0	0.20	63507.56	6.351	12284.597	0.10
22	61.1	0.10	66000.99	6.600	6475.428	0.11
23	61.4	0.30	73368.09	7.337	20905.363	0.13
24	61.7	0.30	80575.76	8.058	23091.579	0.15
25	**62.0**	**0.30**	**87424.95**	**8.742**	**25200.106**	**0.17**
26	62.3	0.30	93870.89	9.387	27194.376	0.20
27	62.6	0.30	101155.15	10.116	29253.906	0.23
28	62.9	0.30	110557.38	11.056	31756.879	0.26
29	63.0	0.10	114054.27	11.405	11230.583	0.27
30	63.2	0.20	122061.46	12.206	23611.573	0.30
31	63.5	0.30	136101.25	13.610	38724.406	0.34
32	63.8	0.30	149988.56	14.999	42913.471	0.38
33	64.0	0.20	160901.50	16.090	31089.006	0.41
34	64.1	0.10	166248.26	16.625	16357.488	0.43
35	64.4	0.30	184091.80	18.409	52551.009	0.48
36	64.7	0.30	200760.64	20.076	57727.866	0.54
37	65.0	0.30	214598.20	21.460	62303.825	0.60
38	65.3	0.30	228236.94	22.824	66425.272	0.67

Anjunem Dam_ Detail Analysis for Elevation And Area Capacity Table 2021						
SL. NO.	**Contour EL (m)**	**Contour Interval (m)**	**Area**		**Capacity**	
			in Sqm.	***in Hectare***	***Vol. between two consecutive contour surface (in Cum.)***	**Cumulative Vol. *(in M-Cum.)***
39	65.6	0.30	242314.87	24.231	70582.772	0.74
40	65.9	0.30	256552.06	25.655	74830.039	0.81
41	66.0	0.10	261464.72	26.146	25900.839	0.84
42	66.2	0.20	272185.32	27.219	53365.004	0.89
43	66.5	0.30	287563.76	28.756	83962.361	0.97
44	66.8	0.30	303173.87	30.317	88610.645	1.06
45	67.0	0.20	315124.69	31.512	61829.856	1.12
46	67.1	0.10	321853.68	32.185	31848.918	1.16
47	67.4	0.30	341073.14	34.107	99439.023	1.26
48	67.7	0.30	362205.80	36.221	105491.841	1.36
49	68.0	0.30	383972.18	38.397	111926.696	1.47
50	68.3	0.30	404932.63	40.493	118335.721	1.59
51	68.6	0.30	425510.02	42.551	124566.397	1.72
52	68.9	0.30	446803.27	44.680	130846.994	1.85
53	69.0	0.10	454059.80	45.406	45043.154	1.89
54	69.2	0.20	469344.29	46.934	92340.409	1.98
55	69.5	0.30	494909.75	49.491	144638.105	2.13
56	69.8	0.30	519757.24	51.976	152200.047	2.28
57	70.0	0.20	536609.85	53.661	105636.709	2.39
58	70.1	0.10	545144.38	54.514	54087.711	2.44
59	70.4	0.30	569915.08	56.992	167258.919	2.61
60	70.7	0.30	593994.73	59.399	174586.472	2.78
61	71.0	0.30	616201.02	61.620	181529.362	2.96
62	71.3	0.30	640711.35	64.071	188536.855	3.15
63	71.6	0.30	665811.20	66.581	195978.382	3.35
64	71.9	0.30	692160.43	69.216	203695.744	3.55
65	72.0	0.10	701202.76	70.120	69668.159	3.62
66	72.2	0.20	718710.94	71.871	141991.370	3.76
67	72.5	0.30	745062.28	74.506	219565.982	3.98
68	72.8	0.30	771398.67	77.140	227469.141	4.21
69	73.0	0.20	789639.35	78.964	156103.802	4.37
70	73.1	0.10	798487.33	79.849	79406.334	4.45
71	73.4	0.30	825717.67	82.572	243630.750	4.69
72	73.7	0.30	852551.86	85.255	251740.429	4.94
73	74.0	0.30	878856.57	87.886	259711.264	5.20
74	74.3	0.30	904964.24	90.496	267573.122	5.47
75	74.6	0.30	929977.17	92.998	275241.212	5.75
76	74.9	0.30	955909.43	95.591	282882.990	6.03

Advance Land & Hydrography Survey India Pvt. Ltd.
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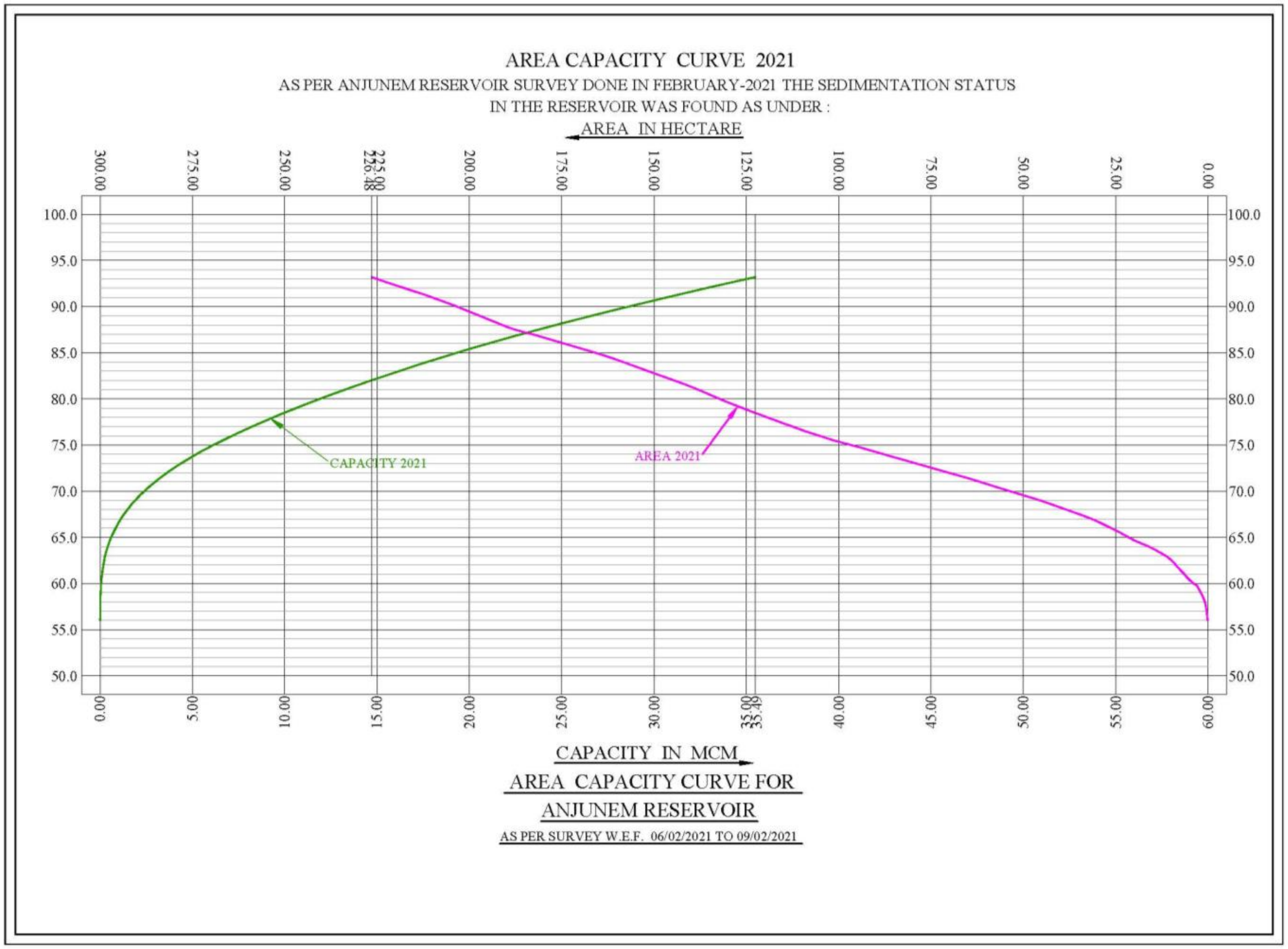
P.S.-Domjur
Howrah
711 403
Vichitra SP-46, (KWIC)

Anjunem Dam_ Detail Analysis for Elevation And Area Capacity Table 2021						
SL. NO.	Contour EL (m)	Contour Interval (m)	Area		Capacity	
			in Sqm.	*in Hectare*	*Vol. between two consecutive contour surface (in Cum.)*	Cumulative Vol. *(in M-Cum.)*
77	75.0	0.10	965505.13	96.551	96070.728	6.12
78	75.2	0.20	984705.87	98.471	195021.100	6.32
79	75.5	0.30	1012489.20	101.249	299579.259	6.62
80	75.8	0.30	1036488.93	103.649	307346.718	6.93
81	76.0	0.20	1052478.29	105.248	208896.722	7.13
82	76.1	0.10	1060458.76	106.046	105646.852	7.24
83	76.4	0.30	1084136.07	108.414	321689.224	7.56
84	76.7	0.30	1105783.86	110.578	328487.990	7.89
85	77.0	0.30	1126374.82	112.637	334823.802	8.23
86	77.3	0.30	1146390.94	114.639	340914.863	8.57
87	77.6	0.30	1167315.61	116.732	347055.982	8.91
88	77.9	0.30	1187716.45	118.772	353254.809	9.27
89	78.0	0.10	1194430.83	119.443	119107.364	9.39
90	78.2	0.20	1207566.40	120.757	240199.722	9.63
91	78.5	0.30	1226963.89	122.696	365179.543	9.99
92	78.8	0.30	1246434.06	124.643	371009.692	10.36
93	79.0	0.20	1259768.11	125.977	250620.217	10.61
94	79.1	0.10	1266369.50	126.637	126306.881	10.74
95	79.4	0.30	1285655.03	128.566	382803.679	11.12
96	79.7	0.30	1304373.65	130.437	388504.301	11.51
97	80.0	0.30	1322225.83	132.223	393989.922	11.90
98	80.3	0.30	1340224.18	134.022	399367.502	12.30
99	80.6	0.30	1357356.17	135.736	404637.053	12.71
100	80.9	0.30	1375223.61	137.522	409886.966	13.12
101	81.0	0.10	1380984.53	138.098	137810.407	13.26
102	81.2	0.20	1392623.94	139.262	277360.847	13.53
103	81.5	0.30	1411522.78	141.152	420622.008	13.95
104	81.8	0.30	1431373.48	143.137	426434.439	14.38
105	82.0	0.20	1445406.45	144.541	287677.993	14.67
106	82.1	0.10	1452345.60	145.235	144887.603	14.81
107	82.4	0.30	1473711.70	147.371	438908.596	15.25
108	82.7	0.30	1495077.17	149.508	445318.330	15.70
109	83.0	0.30	1515142.49	151.514	451532.948	16.15
110	83.3	0.30	1536041.48	153.604	457677.595	16.61
111	83.6	0.30	1557041.68	155.704	463962.474	17.07
112	83.9	0.30	1577506.31	157.751	470182.198	17.54
113	84.0	0.10	1584381.35	158.438	158094.383	17.70
114	84.2	0.20	1598371.74	159.837	318275.309	18.02

Anjunem Dam_ Detail Analysis for Elevation And Area Capacity Table 2021						
SL. NO.	Contour EL (m)	Contour Interval (m)	Area		Capacity	
			in Sqm.	*in Hectare*	*Vol. between two consecutive contour surface (in Cum.)*	Cumulative Vol. *(in M-Cum.)*
115	84.5	0.30	1620182.10	162.018	482783.076	18.50
116	84.8	0.30	1643076.12	164.308	489488.732	18.99
117	85.0	0.20	1658770.07	165.877	330184.619	19.32
118	85.1	0.10	1667024.38	166.702	166289.723	19.49
119	85.4	0.30	1691746.04	169.175	503815.564	19.99
120	85.7	0.30	1717149.55	171.715	511334.339	20.50
121	86.0	0.30	1742701.00	174.270	518977.583	21.02
122	86.3	0.30	1768626.88	176.863	526699.182	21.55
123	86.6	0.30	1795006.45	179.501	534544.999	22.08
124	86.9	0.30	1821322.68	182.132	542449.370	22.62
125	87.0	0.10	1830385.89	183.039	182585.429	22.81
126	87.2	0.20	1849062.79	184.906	367944.868	23.17
127	87.5	0.30	1877213.92	187.721	558941.506	23.73
128	87.8	0.30	1898312.54	189.831	566328.969	24.30
129	88.0	0.20	1910983.39	191.098	380929.593	24.68
130	88.1	0.10	1917135.61	191.714	191405.950	24.87
131	88.4	0.30	1935312.07	193.531	577867.152	25.45
132	88.7	0.30	1953315.78	195.332	583294.176	26.03
133	89.0	0.30	1971631.71	197.163	588742.123	26.62
134	89.3	0.30	1989939.47	198.994	594235.677	27.22
135	89.6	0.30	2008261.12	200.826	599730.088	27.82
136	89.9	0.30	2027059.17	202.706	605298.042	28.42
137	90.0	0.10	2033439.98	203.344	203024.957	28.62
138	90.2	0.20	2046408.19	204.641	407984.817	29.03
139	90.5	0.30	2066405.70	206.641	616922.083	29.65
140	90.8	0.30	2086949.54	208.695	623003.285	30.27
141	91.0	0.20	2100964.84	210.096	418791.438	30.69
142	91.1	0.10	2108018.73	210.802	210449.178	30.90
143	91.4	0.30	2129746.92	212.975	635664.846	31.54
144	91.7	0.30	2152216.90	215.222	642294.573	32.18
145	92.0	0.30	2175256.56	217.526	649121.019	32.83
146	92.3	0.30	2198710.84	219.871	656095.110	33.48
147	92.6	0.30	2222154.36	222.215	663129.780	34.15
148	92.9	0.30	2244871.91	224.487	670053.941	34.82
149	93.0	0.10	2251992.82	225.199	224843.236	35.04
150	**93.2**	**0.20**	**2264811.31**	**226.481**	**451680.412**	**35.49**

Table 5-Capacity area Table of Anjunem Dam 2021

13.1.1Area Capacity Curve 2021:-



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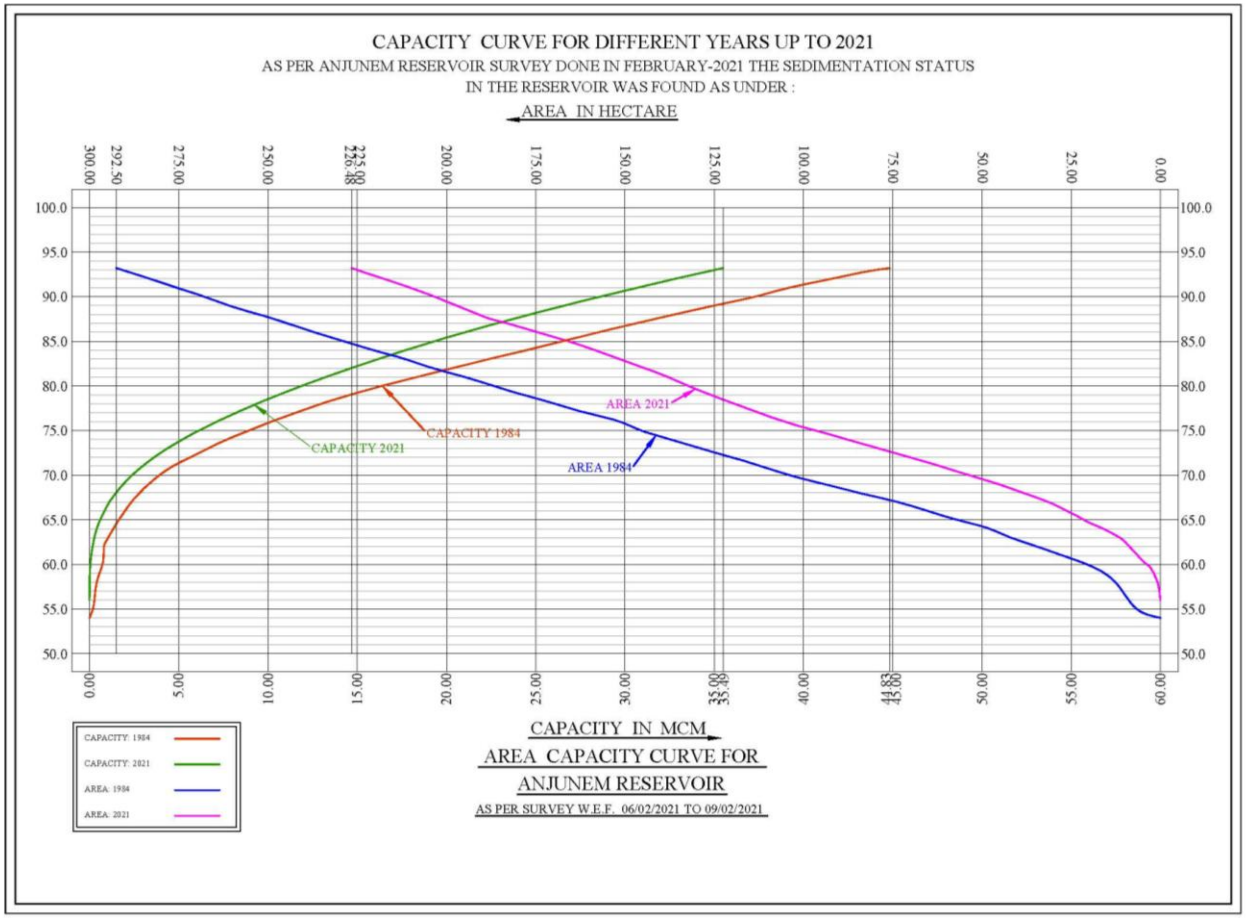
13.1.2 Capacity Curve of different years in 1984 & 2021:-



Assessment of effects of Sedimentation on performance of Dam and balance life of Dam (ii)

This section has been analyzed the **Mathematical Modeling Studies for 100 years at 10 years interval by the reference I.S. 12182-1987 and I.S. 5477 Part-II.**

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13.2 Assessment of effects of Sedimentation on performance of Dam and Balance life of Dam (I.S. 12182-1987):-

This section has been described "I.S. 12182-1987" "Guidelines for determination of effects of sedimentation in planning and performance of Dams". C.B.I & P Publication on the subject and I.S 5477 part-II "Fixing Capacities of Dams – Dead storage" which is described respectively in the report.

IS : 12182 - 1987

Indian Standard

GUIDELINES FOR DETERMINATION OF EFFECTS OF SEDIMENTATION IN PLANNING AND PERFORMANCE OF RESERVOIRS

0. FOREWORD

0.1 This Indian Standard was adopted by the Bureau of Indian Standards on 29 September 1987, after the draft finalized by the Reservoirs Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The storage reservoirs built across rivers or streams lose their capacity on account of deposition of sediment. This deposition of sediment which takes place progressively in time reduces the active capacity of the reservoir which in turn affects the regulating capability of the reservoir to provide the outputs of water through passage of time. Accumulation of sediment at or near the dam may interfere with the future functioning of water intakes and hence affects decisions regarding location and height of various outlets. It may also result in greater inflow of sediment into the canals/water conveyance systems provided at the reservoir. Problems of rise in flood levels in the head reaches and unsightly deposition of sediment from recreation point of view may also crop up in course of time.

0.2.1 Water resources systems operate over a long period of time and are subject to ever increasing demand for water for various purposes. Besides, long term changes in terms of technology and production functions are also encountered. Man-made changes taking place in the river basin and consequent changes in hydrologic regime controlling the water inputs over long term periods are also encountered and have to be provided for (All these factors are to be considered and taken into account while assessing performance of any reservoir project). In this context, sedimentation of reservoirs is to be viewed as an additional factor which has to be considered and its effects studied and evaluated on the reservoir performance.

0.3 In the formulation of this standard, due weightage has been given to the practices prevailing in the field in this country. This has been met by deriving assistance from Chapter II and III of CBI & P Technical Report number 19.

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IS : 12182 - 1987

1. SCOPE

1.1 This standard lays down guidelines for determining the various effects of sedimentation on the performance of reservoir projects in order to make suitable allowances in the design of such projects at the time of initial planning.

2. TERMINOLOGY

2.0 For the purpose of this standard, the definitions given in IS : 4410 (Part 6)-1983* and the following shall apply.

2.1 Dead Storage — Storage of reservoir not susceptible to release by means of the in-built sluices/outlets.

2.2 Economic Life — If at any point of time, the benefits likely to accrue in further operation of the reservoir compare unfavourably under the relevant economic criteria with the future costs involved in operating and maintaining the system, but excluding any element to cover the past costs incurred, the reservoir shall be said to have reached the end of the economic life.

2.3 Feasible Service Time — For a specified purpose, the period or notional period for which the reservoir provided or is/was expected to provide a part of planned benefit in respect of storage in the reservoir being impaired by sedimentation. Customarily, it is estimated as the time after which the new zero elevation of the reservoir would equal the sill of the outlet relevant for the purpose.

2.4 Full Service Time — For a specified purpose, the period or notional period for which the reservoir provided or is/was expected to provide, a part of the full planned benefit inspite of sedimentation.

2.5 New Zero Elevation — The level up to which all the available capacity of the reservoir was or is expected to be lost due to progressive sedimentation of the reservoir up to the specified time.

NOTE — New zero elevation is a time related concept and as sedimentation progresses, the new zero elevation may rise. Thus specified time should be any length of time such as full service time, feasible service time, etc.

3. PROBLEMS ASSOCIATED WITH SEDIMENTATION OF RESERVOIR

3.1 Following are the main effects of sedimentation on the reservoir:

a) The reduction of the active storage capacity which may reduce the capability of the reservoir to deliver the benefits which could have been delivered by the reservoir but for sedimentation. The

*Glossary of terms relating to river valley projects: Part 6 Reservoirs (*first revision*).

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progressive reduction of the active storage capacity may reflect on the outputs from the reservoir in following ways:

1) It may reduce the dump or secondary output. However, where demands have not grown as expected, this effect may not be felt. In years of exceptional good run or secondary off, there may be no reduction of dump outputs.

2) It may reduce availability of firm water in marginal years by increase in both the number and quantum of failures. However, in very bad years where no spills would have occurred even otherwise, the number and quantum of failures may remain unaffected by reduction in active storage capacity. Some reduction of benefits from the existing reservoir projects as a result of sedimentation of active storage capacities is inevitable. However, efforts may be made to make the best use of remaining storage capacity as described in 5.

b) Sedimentation at or near the dam face may tend to block the outlet causing difficulties in operation of the gates. Sedimentation up to intake of the outlet may induce more sediment to be carried through the conservation outlets, thus causing problems of sedimentation of canals, machinery parts, etc. Elevation to which sediment will accumulate at the dam in a given period of time affects the design elevation of outlets for water withdrawals, namely, the sill level of canal's taking off from reservoir and power penstock sills. Location of these outlets is, however, also dependent on other considerations like command areas to be covered and minimum head required for functioning of turbines. In cases where outlet elevations are controlled by above considerations, the effect of sediment accumulation may pose no problem. Sedimentation may cause operational difficulties by tending to jam the intake gates of the outlet when new zero elevation reaches above the gate sill. The problem is more serious for gates which are not frequently operated, and for situations where early floods occur when reservoir is low deposit sediment near the intake. However, in frequently operated gates, a local deep approach channel may develop and allow withdrawal of water. However, in such cases, difficulties caused by passage of sediment in irrigation canals, power houses, etc, may become serious.

c) Sediment accumulation at the dam face may increase the loading on the masonry/concrete dam structure beyond what has been provided for.

d) Sedimentation in upper portion of the reservoir may change the back water profile from what it would have been put for sedimentation. The increase in flood levels upstream of the reservoir may cause additional submergence, formation of marshy lands, etc.

e) The river regime at the entry to the reservoir may get affected due to sediment deposits. Delta formation and braided river pattern may result and this may be unsightly. Tree growth in the delta lends increase evapotranspiration.

f) The operation constraints for a reservoir may necessitate certain minimum reservoir level and filling generally starts at around same level or range of levels. Over a period of years, large deposits of sediment may be built up in the reservoir. The depth of sediment upstream and downstream of this location is small, resulting in a sort of hump in the reservoir bed. This hump acts as a natural barrier to the flow of sediment closer to the dam. The deleterious effect of this hump formation is the early reduction of live storage capacity.

g) The process of sedimentation in reservoirs may also increase the turbidity of water resulting in the environment problems like deterioration of water quality and reduction of visibility in the reservoir water for fish survival.

4. STUDY OF EFFECTS OF RESERVOIR SEDIMENTATION

4.1 The study normally comprises of the following:

a) Performance assessment with varying rate of sedimentation, and

b) Likely effects of sedimentation at dam face.

In special cases where effects of sedimentation on backwater levels are likely to be significant, backwater studies would be useful. Similarly, special studies to bring out delta formation regime changes may be of interest.

4.2 Performance Assessment (Simulation) Studies with Varying Rate of Sedimentation

4.2.1 The following steps are involved for simulation studies:

a) Selection of annual sediment yields into the reservoir or the average annual sediment yield, and of trap efficiency expected;

b) Distribution of sediment within the reservoir to obtain a sediment elevation and capacity curve at any appropriate time;

c) Simulation studies with varying rate of sedimentation; and

d) Assessment of effect of sedimentation.

4.2.2 *Sediment Yield Assessment*

4.2.2.1 Estimation of sediment yield from the catchment area above the reservoir is usually made using river sediment observation data or more commonly from the experience of sedimentation of existing reservoirs with similar characteristics. On adopting the first procedure, it is usually necessary (though often not complied within practice) to evolve proper sediment water discharge rating curve and combine it with flow duration (or stage duration curve) based on uniformly spaced daily or shorter time units in case of smaller river basins. Where observed stage/flow data is available for only shorter periods, these have to be suitably extended with the help of longer data on rainfall to eliminate, as far as possible, the sampling errors due to shortness of records. The sediment discharge rating curves may also be prepared from hydraulic considerations using sediment load formulae, that is, modified Einstein's procedure but this has not yet become popular. It is also necessary to account for the bed load which may not have been measured. While bed load measurement is preferable; when it is not possible, it is often estimated as a percentage generally ranging from 5 to 20 percent of the suspended load. However, practical means of measuring bed load of sediment needs to be undertaken particularly in cases where high bed loads are anticipated. To assess the volume of sediment that would deposit in the reservoir, it is further necessary to make estimates of average trap efficiency for the reservoir in question and the likely unit weight of sediment deposits, time averaged over the period selected. The trap efficiency would depend mainly on the capacity inflow ratio but would also vary with location of controlling outlets and reservoir operating procedures. Computation of reservoir trap efficiency may be made using the trap efficiency curves such as those developed by Brune and by Churchill. An illustration of these computations and curves is given in Appendix A.

4.2.2.2 The density of deposited sediment would vary with the composition of the deposits, the location of the deposit within the reservoir, the flocculation characteristics of clay and water, and the age of the deposit. For coarse material (0·062 5 mm and above), variation of density with location and age may be unimportant. For silt and clay, this may be significant. Normally, a time and space average density of these fractions, applicable for the period under study is required for finding the overall volume of deposits. For this purpose, the trapped sediment for the period under study would have to be classified in fractions by corrections in inflow estimates of the fractions by trap efficiency. Most of the sediment removed from the reservoir should be from the silt and clay fraction. In some special cases, local estimates of densities at a point in the reservoir may be required instead of average density over the reservoir.

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4.2.2.3 The reservoir surveys give valuable additional information regarding the rate of sediment accumulation. This information may be of guidance in deciding the annual sediment inflow and deposition for the problem of catchment. However, as given in **4.2.2.4**, information obtained through capacity re-survey of reservoirs would have little use unless it is accurate enough. While transferring the rates observed in adjacent reservoir(s), considerations for differences in the sediment production or trapping characteristics of the cases involved have to be kept in view.

4.2.2.4 Estimates of annual sediment yield/sedimentation rate assessed from past data are further required to be suitably interpreted and where necessary, the unit rates which would apply to the future period are computed by analysing data for trends or by making subjective adjustments for the likely future changes. Where the contributing drainage area is likely to be reduced by upstream future storages, only such of the projects as are under construction or which have the same priority of being taken up and completed as the project in question are considered for assessing the total sediment yield. Sediment observation data (*see* IS : 4890-1968*) is necessary if the yield is being assessed from hydrometric data. If observational methods are inadequate, the possibility of large errors should be considered. For drawing conclusions from reservoir re-surveys, it is important that reduction of at least 10 percent or more has been observed in the capacities of the two successive surveys; if this is not done, inaccuracies in the successive surveys will distort the estimation of the capacity reduction between the surveys. If the loss of capacity is small, useful conclusions may not be forthcoming, and in such cases, river sediment measurements with its large observational errors may still provide a better estimate. It is essential to make a proper assessment of sediment yield for reservoir under study taking relevant factors into account. Any adhoc adoption of a sediment yield rate, from experience not fully analysed, may lead to large errors. The range recommended in **3.2.3** of IS : 6518-1972† may at best be used for rough reconnaissance level studies [*see* IS : 5477 (Part 2)-1969‡].

4.2.3 *Distribution of Sediment Volume* — Once an assessment of expected volume of total sediment deposition for the required time period has been made, the revised elevation area capacity curves of the reservoir are prepared by using empirical area reduction methods.

4.2.4 *Simulation Studies with Varying Rate of Sediment* — The following are the two ways in which the effect of sedimentation may be considered in the simulation:

a) The first method considers the progressive reduction of capacity every year or for blocks of a few years, and as the simulation

*Methods for measurement of suspended sediment in open channels.
†Code of practice for control of sediment in reservoirs.
‡Methods for fixing the capacities of reservoirs: Part 2 Dead storage.

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progresses, uses the newly updated curve. This method would be more appropriate in bringing out the progressive effects on the reservoir; however, it requires that the simulation be carried out for a long period up to which the benefits of the project are required to be monitored through the simulation.

b) The second method lumps the progressive effect of sedimentation up to an appropriate time horizon up to which no reduction in firm target benefits is contemplated (full service time) and considers situation as at the end of that period throughout the simulation. Thus, though the performance as given by this method is the one that considers the effect of sedimentation up to that period (full service time), the progressive reduction of the dump or secondary benefits within that period should not be brought out in this method. The main advantages of this method are:

1) It is relatively simple, and
2) It does not require that the period of simulation should correspond to the full service time.

4.2.5 *Assessment of Effect of Sedimentation on Outputs* — The comparison of the sedimentation studies would bring out the effect of sedimentation, as a vector of the differential performance, as time progresses if method given in **4.2.4**(a) is followed. If the method given in **4.2.4**(b) is followed, it would bring out the change in the range and distribution of the performances over the time period considered. If the studies are for planning purposes, changes in the project features, and necessary progressive adjustment in targetted outputs beyond the full service time would become apparent and the studies may be repeated after modifying the planning decisions.

5. PERFORMANCE ASSESSMENT FOR STORAGE RESERVOIR

5.1 General — The performance of reservoir project under varying hydrologic inputs to meet varying demands is required to be assessed. Although analytical probability based methods are available to some extent, simulation of the reservoir system is the standard method. The method is also known as the working tables, sequential routing, performance assessment studies, etc. In this method, the water balance of the reservoirs and of other specific locations of water use and constraints in the systems are considered. All inflows to and outflows from the reservoirs are worked out to decide the changed storage during the period. In simulation studies, the inflows to be used may be either historical inflow series, adjusted for future upstream water use changes or a synthetically generated series so adjusted. Whichever approach is used, it shall be used uniformly for assessment of alternate scenarios in regard to sedimentation [*see* IS : 5477 (Part 3)-1969*].

NOTE — A synthetic generation of hydrologic series is a technique which involves mathematical modelling of the statistical properties of historical series and the activation of the model to generate alternate equally likely sequences.

5.1.1 A set of practicable and pre-determined operation policies is essential, to such studies; so is the idea of a firm demand which the reservoir shall meet, as long as possible, within the policy and physical limitations. For this purpose, firm irrigation and power and other demands which the reservoir should meet are to be pre-determined. Demands over and above firm demands are considered as secondary or dump demands, meeting of which, although beneficial is not obligatory.

5.1.2 The acceptability of performance as seen in the simulation is decided by checking if the firm demands have been met with the desired reliability: that is, whether these meet the acceptability criteria. In case, these are not met or the performance is better than required, it is customary to change the assumptions and conduct simulation study again in the planning phase of the project. In general for irrigation and hydro power projects, it is customary to adopt the following acceptability criteria:

a) Any year or water year in which the firm demands are not met fully in each time period separately is labelled as a failure year.

b) The ratio of failure years to the total years of simulation is determined. For irrigation and hydro-power, the ratio shall not exceed 0·25 and 0·1 respectively. The evaluation of performance may also be made through economic analysis considering the series of benefits from year to year during the period of simulation.

5.2 Time Units and Period of Simulation

5.2.1 In general, for within the year projects, a monthly simulation is sufficient for assessing conservational benefits. Shorter period simulation is required for assessing benefits of flood control and secondary power. Units longer than one month may be used for carry over projects. The period of simulation has to be long enough to contain different hydrologic situations which are experienced (*see also* **5.1**).

5.3 Inflows and Demands — The water inflows in the desired time units may be based on the historical data as observed, historical as estimated from hydrologic observations of related phenomenon, or synthetic hydrologic data. The last method has the advantage that it does not make any assumption about the actual flows repeating

*Methods for fixing the capacities of reservoirs: Part 3 Live storage.

themselves. In all cases, observed trends in hydrologic data may be projected in the future operational period. Similarly, the effect of the man-made future upstream development may be incorporated, either in the form of time dependent changes, or in the form of scenario studies, with a pseudo stationary approach with different levels of development. Pattern of firm demand is decided on the basis of assessment of future energy requirement. Seasonal requirements may or may not be built in the demands. The growth of demands after construction may also be considered.

6. STANDARD PROCEDURES FOR PLANNING

6.1 Procedures for New Storages — A rough assessment of seriousness of the problem is necessary to classify the reservoir sedimentation problem as insignificant, significant or serious. Assessment of reservoir sedimentation problem, in a particular case, may be made by comparing the expected average annual volume of sediment deposition with the gross capacity of the reservoir. If ratio is more than 0·5 percent per year, the problem is usually said to be serious and special care is required in estimating the sediment yields from the catchment. If it is less than 0·1 percent per year, the problem of siltation may be insignificant and changes in reservoir capacity can be neglected for studies of reservoir performance. For cases falling between these two limits, the sedimentation problem is considered significant and requires further studies.

6.1.1 The following studies are required if the problem is insignificant:

a) No simulation studies with sediment condition is necessary.

b) The feasible service time for the project may be decided. Sediment distribution studies to ensure that the new zero-elevation does not exceed the dead storage level may be made.

6.1.2 The following studies are required if the problem is significant but not serious:

a) Both the full service time and feasible service time for the reservoir may be decided.

b) Simulation studies for conditions expected at the end of full service time may be made by procedure explained in **4.2.4**(a) to ensure that firm outputs with required dependability are obtained. The studies used also assess non-dependable secondary outputs, if relevant, available at the end of this period. Studies without sedimentation, with the same firm outputs should bring out the additional potential secondary outputs which may be available in the beginning, and this information may be used, if required, in the economic analysis, using a linear decrease of these additional benefits over the full service time.

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c) No simulation studies beyond full service time are essential.

d) Studies as described in **6.1.1** for feasible service time are essential.

6.1.3 The following studies are required if sedimentation problem is serious:

a) All studies as described in **6.1.2** would be required.

b) The secondary benefits available in the initial years should be more in such cases. If these are being utilised, for a proper assessment of the charge of these, a simulation at half of full service time should be required.

c) In these cases, the drop of benefits after the full service time may be sharper. To bring out these effects, a simulation of the project at the end of the feasible service time is required to be done.

d) Considering (a), (b), and (c) together, it may be worthwhile to resort to the more realistic method, given in **4.2.4**(a) in simulation for cases where the problem is serious. For this purpose, it should be sufficient to consider sediment trapped in every 10-year block, and to use the expected sedimental elevation area capacity curve at the end of each 10-years block, for simulation of that block.

7. PROCEDURE FOR EXISTING PROJECTS

a) Assess the present elevation area curve either by reservoir re-surveys or by projecting from the earlier survey data, using the estimates of sediment yield and its distribution.

b) Decide the target firm level of the outputs. To start with, this may be based on the earlier planning or on existing situation.

c) Simulate the reservoir by the method described in **4.2.4**(a). It should suffice if 10-yearly block is considered and expected sedimented elevation area capacity curve at the end of each 10-years block is considered for simulation of that block.

d) Screen the performance to see if the frequency of failures, after proper smoothening tends to cross from an acceptable frequency to an unacceptable frequency (*see* **3.1**). If this is happening, estimate the time of switchover from an acceptable frequency of failures to an unacceptable frequency. This represents the end of the full service time, thus giving an estimate of the residual full service time. If the total full service time (lapsed period plus remaining period) is more or less equal to the prescribed full service time in the criteria, this would show that the actual sedimentation has no effect on the project.

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e) For period beyond the full service time, it should be necessary to determine the policy changes in operation which may include measures discussed in **7.1** and **7.2**.

7.1 In hydro-electric projects, the slow reduction in the total energy generation as a result of partial loss of active capacity may be adjusted in the system by reducing the load factor without losing the peaking benefits. It is also important to note here that even if the reservoirs for such projects were to be silted up completely, the head available in the reservoir would give a permanent benefit.

7.2 In the case of irrigation projects, the reduction in availability of water may be adjusted to some extent by changing the crop pattern and/or the dependability criteria.

7.3 The simulation shall have to be repeated with these changes. If it is necessary to bring out the overall effect of sedimentation, or the effect of sedimentation due to change in the estimate of sediment load from the earlier planning, it should be necessary to recompute steps given in **7** (a) to (e) for either the no sedimentation case or for the earlier assumption of sediment rate. The time series of the differences in performance should bring out the differential effect.

7.4 If at any time, the new zero elevation is crossing the sill levels of an outlet of a primary purpose, this should signify the end of the feasible service period unless with new engineering measures (*see* **7.2**) or due to natural development of an approach channel this may be extended.

8. LIFE OF RESERVOIR AND DESIGN CRITERIA

8.1 General — The reservoir exists for a long time and the period of its operation should normally check large technological and socio-economic changes. The planning assumptions about the exact socio-economic output are, therefore, likely to be changed during operation, and similarly, the exact implication of socio-economic differences in the output due to sedimentation are difficult to assess. The ever increasing demands due to both increase of population and increases in per capita needs are of a larger magnitude than the reductions in outputs, if any, of existing reservoirs. Thus effects of sedimentation, obsolensence, structural deterioration, etc, of reservoirs may require adjustments in future developmental plans and not simply replacement projects to bring back the lost potential. On a regional or national scale, it is the sufficiency of the total economic outputs, and not outputs of a particular project which is relevant. However, from local considerations, the reduction of outputs of reservoir like irrigation and flood control may cause a much greater degree of distress to the population which has got used to better socio-economic conditions because of the reservoir.

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8.2 Life of Reservoir — Life strictly is a term which may be used for system having two functional states 'ON' and 'OFF'. Systems showing gradual degradation of performance and not showing any sudden non-functional stage have no specific life period. Reservoirs fall in the later category.

8.2.1 The term 'life of reservoir' as loosely used denotes the period during which whole or a specified fraction of its total or active capacity is lost. In calculating this life, the progressive changes in trap efficiency towards the end of the period were commonly not considered. In some of the projects, it was assumed that all sedimentation would occur only in the dead storage pocket and the number of years in which the pocket should be filled under this assumption was also sometimes termed as the life of reservoir. This concept was in fact used to decide the minimum size of the pocket. Under this concept, no effect of sedimentation should be felt in the live storage of the reservoir. It has subsequently been established that the silt occupies the space in the live storage of reservoir as well as the dead storage.

8.2.2 It shall not be possible to express the life of the reservoir as a specific period. The concerned life related terms such as economic life, feasible service time and full service time are defined in **2.2** to **2.4**.

8.2.3 If the operation of the reservoir becomes impossible due to any structural defects, foundation defects, accidental damages, etc, this situation should also signify the end of the feasible service time. Before the expiry of this feasible service time, it may be possible to make large changes in the reservoir (for example, new higher level outlets, structural strengthening, etc) or other measures, if it is economically feasible to do so. If these studies are done, the feasible service time may be extended.

8.2.3.1 *Economic life* — By definition, the economic life cannot be more than the feasible service time. In general, for reservoir projects with gravity irrigation, operation and maintenance costs are so small compared to benefits even from much reduced capacity that economic life should be determined by the feasible sedimentation problem; no check should be required.

9. DESIGN CRITERIA FOR NEW PROJECTS

9.1 General Design Criteria — The design criteria given in **9.1.1** to **9.1.3** are recommended.

9.1.1 *Irrigation Projects* — Full service time shall not be less than 50 years after the start of operation. Feasible service time shall not be less than 100 years after the start of operation. For reservoirs with serious sedimentation problem where extension of feasible service time to overcome social distress is perhaps feasible, the period may be suitably reduced, provided detailed studies as detailed therein are done, and also provided that rigorous economic analysis up to the feasible service time and with changing stream of benefits is made.

9.1.2 For hydro-power projects expected to supply power to a community, in isolation the feasible and full service time shall be the same as for the irrigation projects.

9.1.3 For hydro-power projects supplying power to a grid, full service time shall not be less than 25 years. Feasible service time shall not be less than 70 years. For reservoirs with serious sedimentation problem where extension of feasible service time to overcome social distress is perhaps feasible, the periods may be suitably reduced, provided detailed studies as detailed therein are done, and also provided that rigorous economic analysis up to the feasible service time and with changing stream of benefits is made.

10. CONSIDERATION OF EFFECTS OF SOIL CONSERVATION PROGRAMME

10.1 Soil conservation may lead to reduction of sediment. This programme, apart from benefiting downstream reservoir, could have large beneficial effects on production of the protected area. However, because of the different areas benefitted, socio-economic implication, etc, these programmes normally are not included in the economic analysis of the reservoir project. Therefore, any change in trend of sediment yield, attributable to such programmes, may not be considered in assessment of performance of the reservoir. If economic feasibility of the soil conservation programme is to be established, any properly established reduction of yield, and its effect on the reservoir benefits may be considered in that analysis.

10.2 Normally at the project planning stage, the sediment load calculations used in the sedimentation studies are as per the land use existing then. If adverse human actions come into operation in the catchment, it may result into a higher sediment load than the one assumed in the project planning. This should be reflected in the project.

13.2.1 Assessment of effects of Sedimentation on performance of Dam and Balance life of Dam (I.S. 5477 PART-II-1994):-

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Reservoirs Sectional Committee had been approved by the River Valley Division Council.

By providing extra storage volume in the reservoir for sediment accumulation, in addition to the live storage, it is ensured that the live storage, although it contains sediment, will function at full efficiency for an assigned number of years. This volume of storage (in the fixation of which the minimum draw down level is also a major criterion in case of power projects) is referred to as the dead storage and is equivalent to the volume of sediment expected to be deposited in the reservoir during the designed life of the structure.

The distribution pattern of sediments in the entire depth of a reservoir depends on many factors, such as slope of the valley, length of reservoir, constriction in the reservoir, particle size of the suspended sediment and capacity inflow ratio; but the reservoir operation has an important control over other factors. However, a knowledge of this pattern is essential, especially, in developing areas, in order to have an idea about the formation of delta and the recreational spots and the consequent increase in back water levels after the reservoir comes into operation.

This standard (Part 2) was first published in 1969. The present revision has been prepared to incorporate the latest knowledge in this field in this revision an additional figure for determining the type of reservoir has been incorporated in addition to modifying Fig. 1 and 2 and some tables.

This standard consists of four parts, Part 1 covers general requirements, Part 3 covers live storage and Part 4 covers flood storage.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Indian Standard

FIXING THE CAPACITIES OF RESERVOIRS — METHODS

PART 2 DEAD STORAGE

(First Revision)

1 SCOPE

This standard (Part 2) covers the methods for computing the sediment yield and for predicting the probable sediment distribution in the reservoir below normal (full) reservoir level (F.R.L.).

2 REFERENCES

The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
4410 (Part 6) :1983	Glossary of terms relating to river valley projects : Part 6 Reservoirs (*first revision*)
4890 : 1968	Methods of measurement of suspended sediment in open channels
12182 : 1987	Guidelines for determination of effects of sedimentation in planning and performance of reservoirs

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 4410 (Part 6) : 1983 shall apply.

4 MEASUREMENT OF SEDIMENT YIELDS

4.1 The sediment yield in a reservoir may be estimated by any one of the following two methods:

a) Sedimentation surveys of reservoirs with similar catchment characteristics, or

b) Sediment load measurements of the stream.

4.2 Reservoir Sedimentation Survey

4.2.1 The sediment yield from the catchment is determined by measuring the accumulated sediment in a reservoir for a known period, by means of echo sounders and other electronic devices since the normal sounding operations give erroneous results in large depths. The volume of sediment accumulated in a reservoir is computed as the difference between the present reservoir capacity and the original capacity after the completion of the dam. The unit weight of deposit is determined in the laboratory from the representative undisturbed samples or by field determination using a calibrated density probe developed for this purpose. The total sediment volume is then converted to dry-weight of sediment on the basis of average unit weight of deposits. The total sediment yield for the period of record covered by the survey will then be equal to the total weight of the sediment deposited in the reservoir plus that which has passed out of the reservoir based on the trap efficiency. In this way, reliable records may be readily and economically obtained on long-term basis.

4.2.2 The density of deposited sediment varies with the composition of the deposits, location of the deposit within the reservoir, the flocculation characteristics of clay content and water, the age of deposit, etc. For coarse material (0.0625 mm and above) variation of density with location and age may be unimportant. Normally a time and space average density of deposited materials applicable for the period under study is required for finding the overall volume of deposits. For this purpose the trapped sediment for the period under study would have to be classified in different fractions. Most of the sediment escape from getting deposited into the reservoir should be from the silt and clay fractions. In some special cases local estimates of densities at points in the reservoir may be required instead of average density over the whole reservoir.

4.2.3 The trap efficiency mainly depends upon the capacity-in-flow ratio but may vary with location of outlets and reservoir operating procedure. Computation of reservoir trap efficiency may be made using trap efficiency curves, such as those developed by Brune and by Churchill (*see* IS 12182 : 1987).

4.2.4 The sedimentation rates observed in adjacent reservoirs also serve as guide while designing dead storage capacity for a new reservoir, the rate of sedimentation observed in similar reservoirs and/or adjacent basin should be suitably modified keeping in view the density of deposited material, trap efficiency and sediment yield from the catchment.

4.3 Sediment Load Measurements

Periodic samples from the stream should be taken at various discharges along with the stream gauging observations and the suspended sediment concentration should be measured as detailed in IS 4890 : 1968. A sediment rating curve which is a plot of sediment concentration against the discharge is then prepared and is used in conjunction with stage duration curve (or flow duration) based on uniformly spaced daily or shorter time units data in case of smaller river basins to assess sediment load. For convenience, the correlation between sediment concentration against discharge may

IS 5477 (Part 2) : 1994

be altered to the relation of sediment load against run-off for calculating sediment yield. Where observed stage/flow data is available for only shorter periods, these have to be suitably extended with the help of longer data on rainfall. The sediment discharge rating curves may also be prepared from hydraulic considerations using sediment load formula, that is, modified Einstein's procedure.

4.3.1 The bed load measurement is preferable. However, where it is not possible, it may be estimated using analytical methods based on sampled data or as a percentage of suspended load (generally ranging from 10 to 20 percent). This should be added to the suspended load to get the total sediment load.

5 PREDICTING SEDIMENT DISTRIBUTION

5.1 The sediment entering into a storage reservoir gets deposited progressively with the passage of time and thereby reduces the dead as well as live storage capacity of the reservoir. This causes the bed level near the dam to rise and the raised bed level is termed as new zero elevation. It is, therefore, necessary to assess the revised areas and capacities at various reservoir elevations that would be available in future and could be used in simulation studies to test the reservoir performance and also the new zero-elevation.

The following procedure may be adopted for fixing the dead storage level and sill levels of the outlets:

a) The distribution of the estimated sediment load for the feasible service time of the reservoir should be carried out and new zero-elevations should be determined, and

b) The minimum drawdown level is fixed a little above the new zero-elevation computed in (a) above. When other considerations like command area elevation, providing extra head for power generation, etc, prevail, this elevation is fixed higher than one of these.

5.2 Several methods are in use for predicting sediment distribution in reservoirs for design purposes. Either the empirical area reduction method or the area increment method may be used.

5.2.1 *Empirical Area Reduction Method*

This method is based on the analysis of data of sediment distribution. In this method, reservoirs are classified into four types, namely, (a) gorge, (b) hill, (c) flood plain-foot hill, and (d) lake, based on the ratio of the reservoir capacity to the reservoir depth plotted on a log-log scale (*see* Fig. 1). Figures 2 and 3 give the sediment distribution-area design curves for each type of these reservoirs. The equation for the design curve used is:

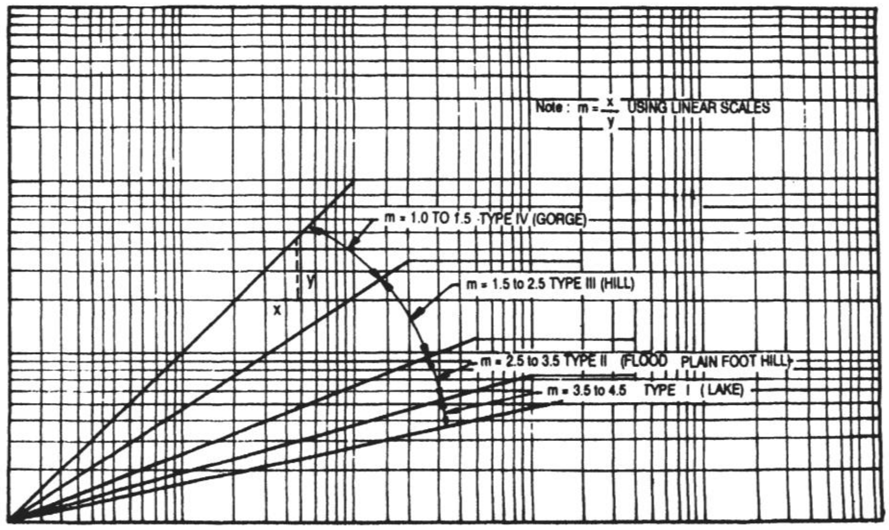
$$A_p = Cp^m (l - p)^n \qquad ......(1)$$

where

A_p = a non-dimensional relative area at relative distance '*p*' above the stream bed, and

C, *m* and *n* = non-dimensional constants which have been fixed depending on the type of reservoir.

5.2.1.1 These curves are used to work out the probable sediment deposition in the reservoir at different depths. This method is more reliable than the area increment method. An example of the usage of this method is given in Annex A.



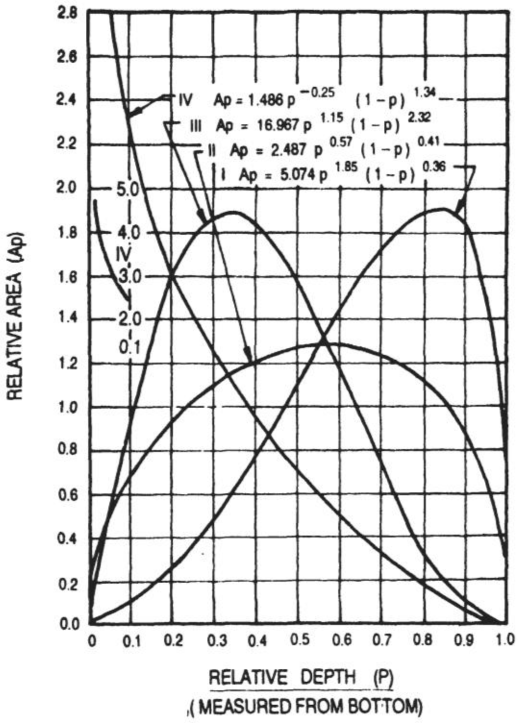


FIG. 2 SEDIMENT DISTRIBUTION – AREA DESIGN CURVES (BASED ON RESERVOIR STORAGE CURVES)

5.2.2 *Area Increment Method*

The basic assumption in this method is that the sediment deposition in the reservoir may be approximated by reducing the reservoir area at each reservoir elevation by a fixed amount. Successive approximations are made. Average end area (or prismoidal formula) is used to compute the reservoir capacities on the basis of reduced surface areas until the total reservoir capacity below the full reservoir level is the same as the predetermined capacity obtained by subtracting the sediment accumulation with time from the original capacity.

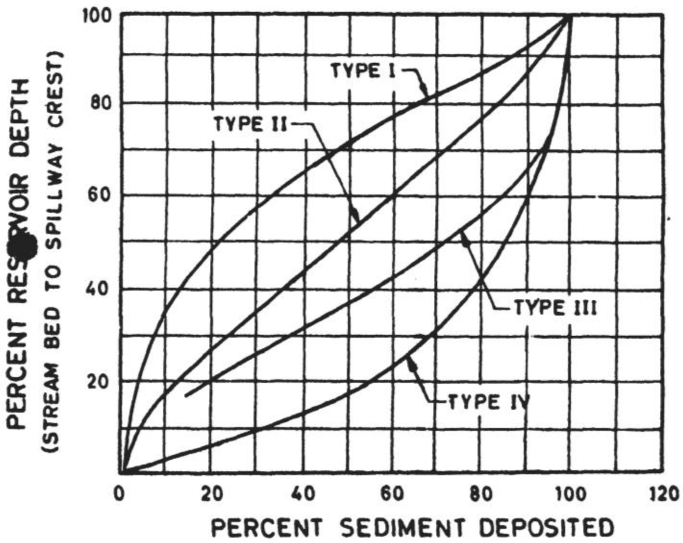
The basic equation in this method is:

$$V_s = A_o (H - h_o) + V_o \qquad ....(2)$$

where

- V_s = the sediment volume to be distributed in the reservoir in hectare metres,
- A_o = the area correction factor in hectares which is original reservoir area at the new zero elevation of the reservoir,
- H = the reservoir depth below full reservoir level (F.R.L.) in metres,
- h_o = the depth in metres to which the reservoir is completely filled with sediment, and
- V_o = the sediment volume below new zero elevation in hectare metres.

5.2.2.1 In other words, the equation mathematically expresses that the total sediment volume V_s consists of two parts, namely, (a) the protion which is uniformly distributed vertically over the height $H - h_o$ with an



area equal to A_o and (b) the portion V_o below the new zero elevation of the reservoir.

5.2.2.2 An example of the usage of this method is given in Annex B.

NOTE – The applicability of this method decreases with the increase in the ratio of $\frac{\text{sediment deposit}}{\text{reservoir capacity}}$. If the hundred years sediment, accumulation exceeds 15 percent of the original capacity, a more exact method should be applied.

5.2.3 ***Moody's Method to Find New Zero Elevation***

This method is used to determine the new zero elevation 0, directly without trial and error process. Two parameters $f(p)$ and $f'(p)$ as explained below are made use of:

$$f(p) = \frac{1 - V(p)}{a(p)} \quad ....(3)$$

$$f'(p) = \frac{S - V(pH)}{H\,A(pH)} \quad ....(4)$$

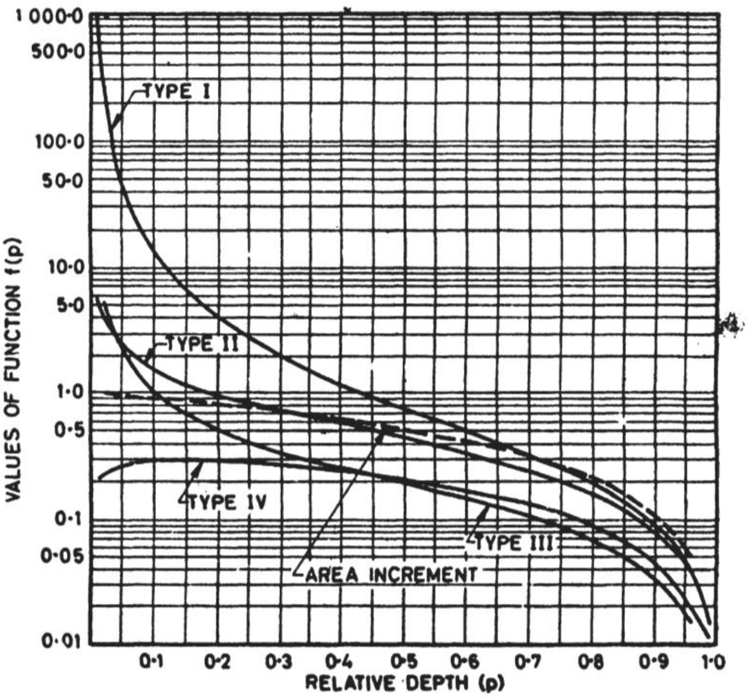
where

- $f(p)$ = a function of the relative depth of reservoir for one of the four types of theoretical design curves,
- $V(p)$ = relative volume at a given elevation,
- $a(p)$ = relative area at a given elevation,
- $f'(p)$ = a function of the relative depth of reservoir for a particular reservoir and its anticipated sediment storage,
- S = total sediment in the reservoir in hectare metres,
- $V(pH)$ = reservoir capacity at a given elevation in hectare metres,
- H = the total depth of reservoir for normal water surface in metres, and
- $A(pH)$ = reservoir area at a given elevation in hectares.

5.2.3.1 Table 1 gives the values of the function $f(p)$ for the four types of reservoirs (*see* **5.2.1**) and Fig. 4 shows the plotting of $f(p)$ against relative reservoir depth, p, for the four types of reservoirs of the empirical area method (*see* **5.2.1**) and also for the area increment method (*see* **5.2.2**).

5.2.3.2 To determine the new zero elevation, $f(p)$ should equal $f'(p)$. This is done graphically by plotting the values of $f'(p)$ and superposing this over the relevant $f(p)$ curve. The intersection gives the relative depth of (P_o) reservoir at new zero elevation after sedimentation. New zero-elevation may be computed by adding the product P_o. H to the original stream bed elevation. After arriving at the new zero elevation, either empirical area method (*see* **5.2.1**) or the area increment method (*see* **5.2.2**) is used.

5.2.3.3 An example to find out the new zero elevation is given in Annex C.



MATHEMATICAL MODELLING STUDIES

The Mathematical modeling studies has been described for 100 years at 10 years interval including I.S. 12182-1987 and I.S. 5477 part-II. The Mathematical Modeling Studies has been tabulated from the next pages.

- **Mathematical Modeling Studies for 100 Years at 10 years interval (I.S.12182-1987 and I.S. 5477 Part-II) :-**

Most natural rivers reach is approximately balanced with respect to sediment inflow and outflow. Dam construction dramatically alters this balance, creating an impounded river reach characterized by extremely low flow velocities and efficient sediment trapping. The impounded reach will accumulate sediment and lose storage capacity until a balance is again achieved, which would normally occur after the impoundment has become filled up with sediment and can no longer provide water storage and other benefits.

Sediments are deposited in reservoirs at all elevations, causing the stage-capacity curve to shift. Empirical methods have been developed to distribute sediment deposits within a reservoir as a function of depth, thereby projecting the shift in the stage-storage curve. There is different method to predict distribution of sediment in the reservoir. The methods are Area-reduction method and Area-increment method. It is mentioned in IS 5477 Part II 1994 "Fixing Capacities of Reservoirs – Dead Storage", the applicability of Area-increment method decreases with the increase in the ratio between sediment deposit and reservoir capacity. It is also cited that Area-reduction method is more reliable. Therefore, Area-reduction method is used in this study. Moody's Method is used to determine the new zero elevation, directly without trial-and-error process. Trap efficiency of reservoir is also estimated for the reservoir. IS 12182 – 1987 1987"Guidelines for Determination of Effects of Sedimentation in Planning and Performance of Reservoirs", is used for finding trap efficiency.

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- **Capacity of reservoir and annual sediment deposition:-**

As per the sedimentation survey of 1984, original allocated capacity computed of 44.83 MCM up to elevation of 93.2 m. Survey done in 2021 shows capacity is 35.49 at elevation of 93.2 m. Salient features of reservoir related to storage in 1984 and 2021 is given below. It is observed that loss of total storage i.e., deposition/accumulation of sediment in 37 years is 9.336 MCM. Deposition of sediment per year is 0.252 MCM/year.

FRL/MWL	93.2 m
Dead storage level	62 m
Capacity at MWL in 1984	44.83 MCM
Capacity at DSL in 1984	0.827 MCM
Capacity at MWL in 2021	35.49 MCM
Capacity at DSL in 1984	0.18 MCM
Live storage in 1984	44 MCM
Dead storage in 1984	0.827 MCM
Live storage in 2021	35.32 MCM
Dead storage in 2021	0.17 MCM

- **Annual Average Inflow:-**

Inflow to dam data is collected from 2009 to 2020. The annual runoff from the catchment along with the mean annual runoff is shown in Fig-18 and Table-6

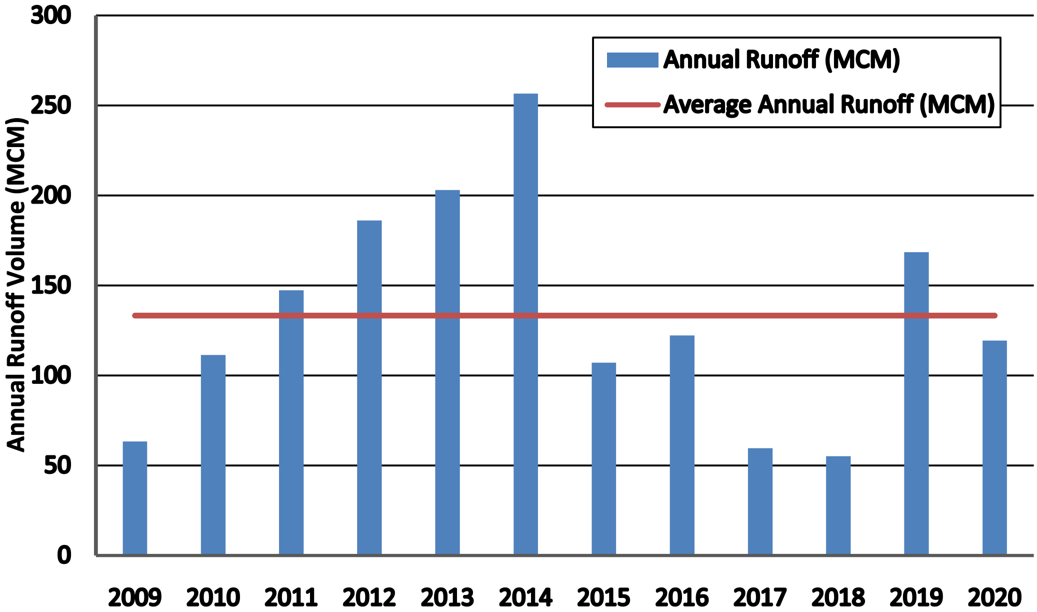

Figure 18- Annual runoff along with average annual runoff

Table 6- Annual runoff along with average annual runoff

Year	Annual Runoff (MCM)
2009	63.424
2010	111.441
2011	147.343
2012	186.128
2013	203.073
2014	256.531
2015	107.09
2016	122.18
2017	59.667
2018	55.079
2019	168.499
2020	119.408
Average	**133.32**

- **Area-reduction method:-**

The Elevation-Area-Capacity curve and is produced for another 100 years at 10 years interval using Area-reduction method. Year 2021 is considered as base year. Elevation-capacity surveyed in 2021 is used as a base. No surface area is available. The average contour area method is used here. The equation is:

$$Volume = H\frac{(A_1 + A_2)}{2}$$

Where H = elevation difference between adjacent contour lines and A1 and A2 are the surface areas enclosed by each contour line. Elevation-Area-Capacity for 2021 is shown in Table-7

Table 7 -Elevation-Area-Capacity in 2021

Elevation m	Area ha	Capacity 10^6 m^3	Elevation m	Area ha	Capacity 10^6 m^3
93.2	229.78	35.49	75	100.31	6.12
92	214.52	32.83	74	84.05	5.20
91	212.98	30.69	73	82.85	4.37
90	200.36	28.62	72	66.18	3.62
89	200.10	26.62	71	65.40	2.96
88	188.16	24.68	70	50.09	2.39
87	186.67	22.81	69	48.87	1.89
86	170.59	21.02	68	34.89	1.47
85	169.50	19.32	67	34.85	1.12
84	154.65	17.70	66	22.70	0.84
83	155.33	16.15	65	24.85	0.60
82	140.80	14.67	64	12.94	0.41
81	141.62	13.26	63	14.33	0.27
80	128.72	11.90	62	4.5	0.18
79	129.60	10.61	60.91	2.5	0.17
78	115.80	9.39	57.91	2	0.10
77	116.27	8.23	54.86	2	0.04
76	101.86	7.13	54	0	0.00

The steps and results are described in this section.

Determine sediment inflow: Volume of sediment deposition is determined from 1984 and 2021survey. Deposition of sediment volume is 9.336 mcm. Deposition of sediment volume per year is 0.252 MCM (9.336/37).

Selection of design curve: Strand and Pemberton state that the reservoir does not change type with continued sediment deposition unless reservoir operation changes. Thus, the stage-capacity plot should be based on the original reservoir bathymetry, not the bathymetry following sediment accumulation. The original depth-capacity (1984) relationship on log-log paper is plotted and the slope m of the fitted line, which is the reciprocal of the slope of the depth versus capacity plot (Fig-19) is calculated. When the slope m does not plot as a straight line, shape type corresponding to the predominate overall slope, or the slope in the area of the reservoir where most of the sediment will deposit, are used. It is noticed that slope m is following straight line above depth 0.2 m i.e., between 62 m and 93.2 m and it is predominant. Therefore, slope in this area is used.

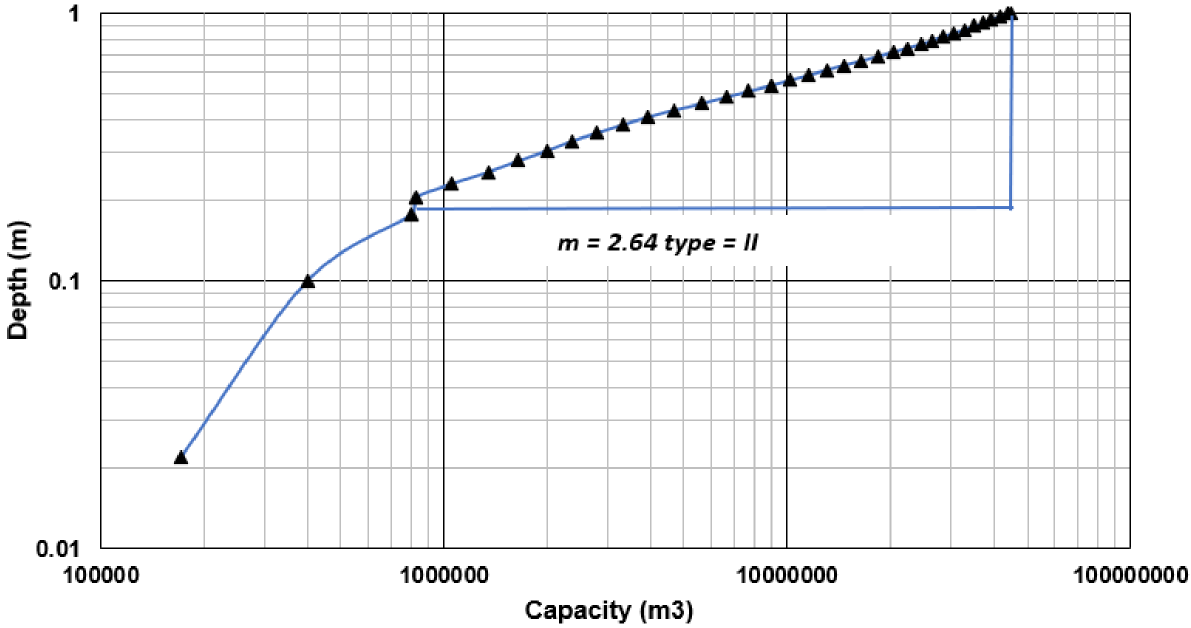

Figure 19- Reservoir depth-capacity relationship for Anjunem Reservoir

The resulting slope m to classify the reservoir shape is given below:

Reservoir shape	Type	m
Lake	I	3.5-4.5
Floodplain-foothill	II	2.5-3.5
Hill and George	III	1.5-2.5
George	IV	1-1.5

The type curves in Fig-20 reflect the tendency for sediment is Floodplain-foothill reservoir i.e., type II.

Compute new zero-capacity elevation at dam: Moody's method is used to estimate new zero elevation. Two parameters f(p) and F is used for this estimation. Function f(p) uses following formula and generate value for the four types of reservoir with respect to relative depth.

$$f(p) = \frac{1 - V(p)}{a\ (p)}$$

Where f(p) = a function of the relative depth of reservoir for one of the four types of theoretical design curves,

V(p) = relative volume at a given elevation,

a(p) = relative area at a given elevation,

Fig-20 shows the plotting off f(p) against relative reservoir depth, p, for the four types of reservoirs and value is given in Table-8.

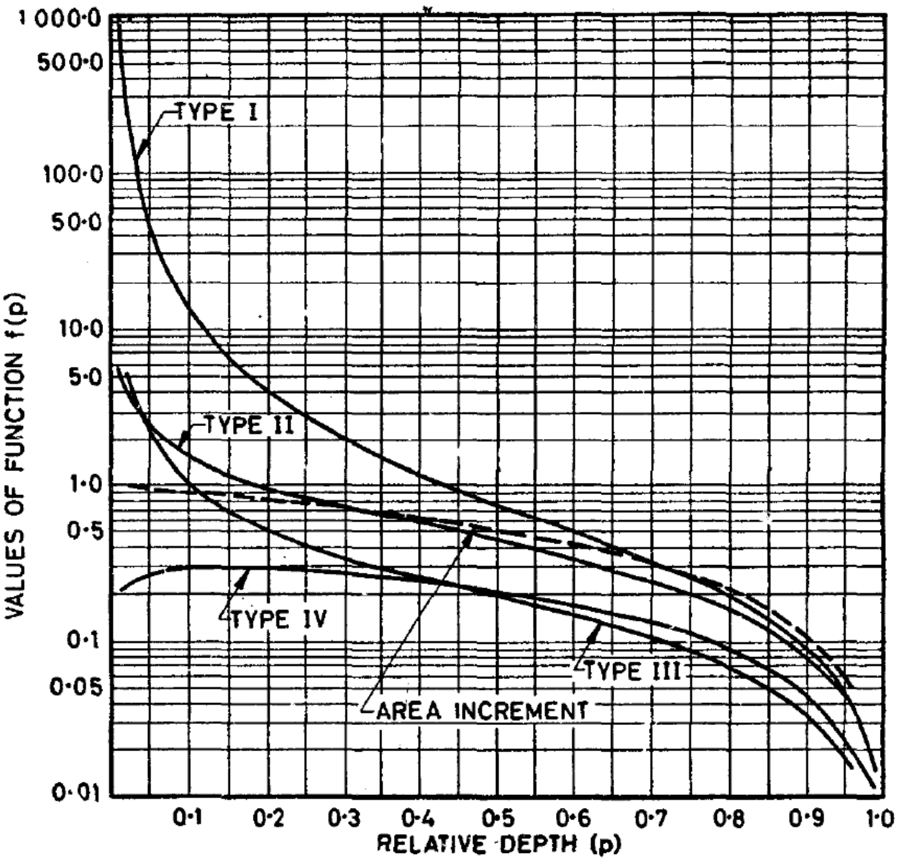

Figure 20-Type curves for determining the new zero depth at the dam.

Table 8-Values of the Function f (p) for the Four Types of Reservoirs

p	I	II	III	IV
0	∞	∞	∞	0
0.01	996.7	5.568	12.03	0.2023
.02	277.5	3.758	5.544	.2330
.05	51.49	2.233	2.057	.2716
.1	14.53	1.495	1.013	.2911
0.15	6.971	1.169	0.6821	0.2932
.2	4.145	0.9706	.5180	.2878
.25	2.766	.8299	.4178	.2781
.3	1.980	.7212	.3486	.2656
.35	1.485	.6323	.2968	.2513
0.4	1.149	0.5565	0.2555	0.2355
.45	.9076	.4900	.2212	.2187
.5	.7267	.4303	.1917	.2010
.55	.5860	.3758	.1657	.1826
.6	.4732	.3253	.1422	.1637
0.65	0.3805	0.2780	0.1207	0.1443
.7	.3026	.2333	.1008	.1245
.75	.2359	.1907	.08204	.1044
.8	.1777	.1500	.06428	0.08397
.85	.1262	.1107	.04731	.06330
0.9	0.08011	0.07276	0.03101	0.04239
.95	.03830	.03590	.01527	.02128
.98	.01494	.01425	.006057	.008534
.99	.007411	.007109	.003020	.002470
1.0	0.0	0.0	0.0	0.0

The elevation-area and capacity curve are used to compute the value of the dimensionless function F at several different pool elevations in the deeper part of the reservoir:

$$F = \frac{S - V_h}{HA_h}$$

Where S = total sediment deposition, V_h = reservoir capacity (m^3) at a given elevation h, H = original depth of reservoir below normal pool, A_h= reservoir area (m^2) at a given elevation h.
The relative depth p is computed as

$$p = \frac{h - h_{min}}{H}$$

Where h_{min} = original bottom elevation
The resulting F and p values on the type curves are presented in Fig-21. The intersection of the plotted F values with the type of curve selected for the reservoir defines the p_0 value for the new zero-capacity elevation at the dam. Intersection occurs at p_0 = 0.25, 0.382, 0.638 for 10 yr, 50 yr and 100 yr respectively.

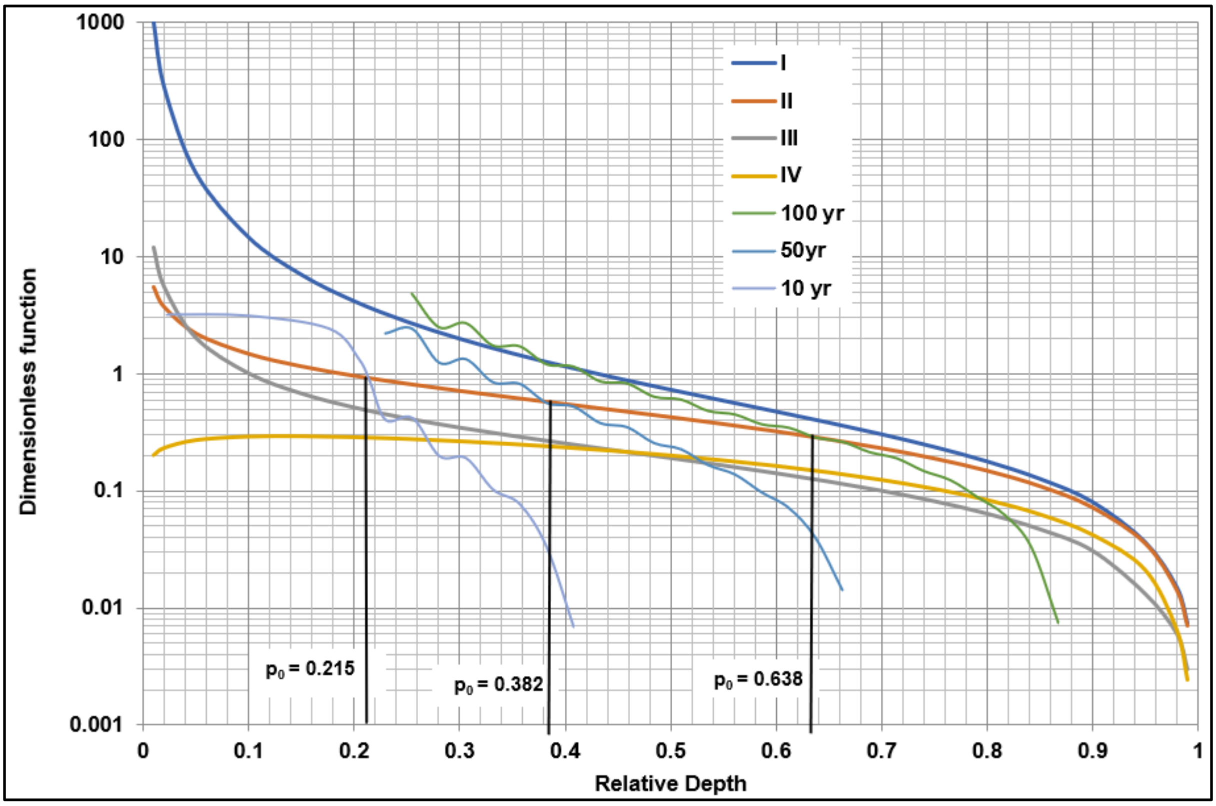

Figure 21-Type curves for determining the new zero depth at the dam based on the dimensionless F function.

The new zero-capacity elevation is given by $h_0 = (p_0H + h_{min})$ = 0.215 (93.2-54) + 54 = 62.428 m for 10 yr. Area corresponding to zero-capacity elevation is computed from original elevation area-capacity curve.

Distribute sediment: The specified volume of trapped sediment is distributed within the reservoir according to the selected type of curve. Fig-22 shows sediment distribution curve for four types of reservoir. The values for relative sediment area 'a' at each relative depth p is estimated (Anjunem Reservoir is Type II) using the equation:

Type II: $a=2.487p^{0.57}(1-p)^{0.41}$

The relative sediment area 'a' at the new zero elevation is computed for 10 yr, a = 0.9376 and the area correction factor is A0/a = 7.465.

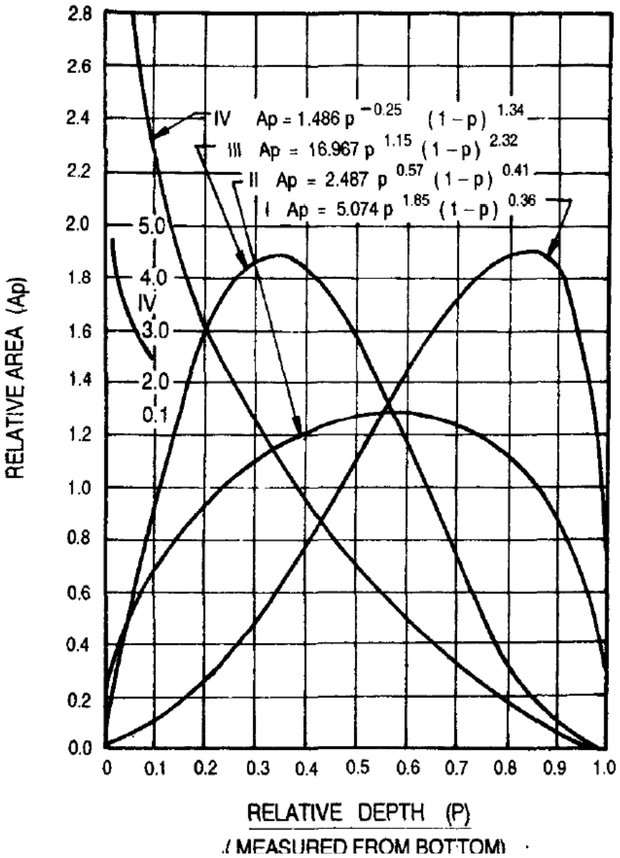

Figure 22-Sediment distribution – Area design curves (Based on reservoir storage curve)

Using aforesaid methodology Elevation-Area-Capacity curve is estimated for every 10-year upto 100 year considering 2021 as base year. Fig-23 and Table-9 shows Elevation-capacity for 10, 30, 50, 70 and 100 year. A sample calculation is given in Appendix A for 30 year.

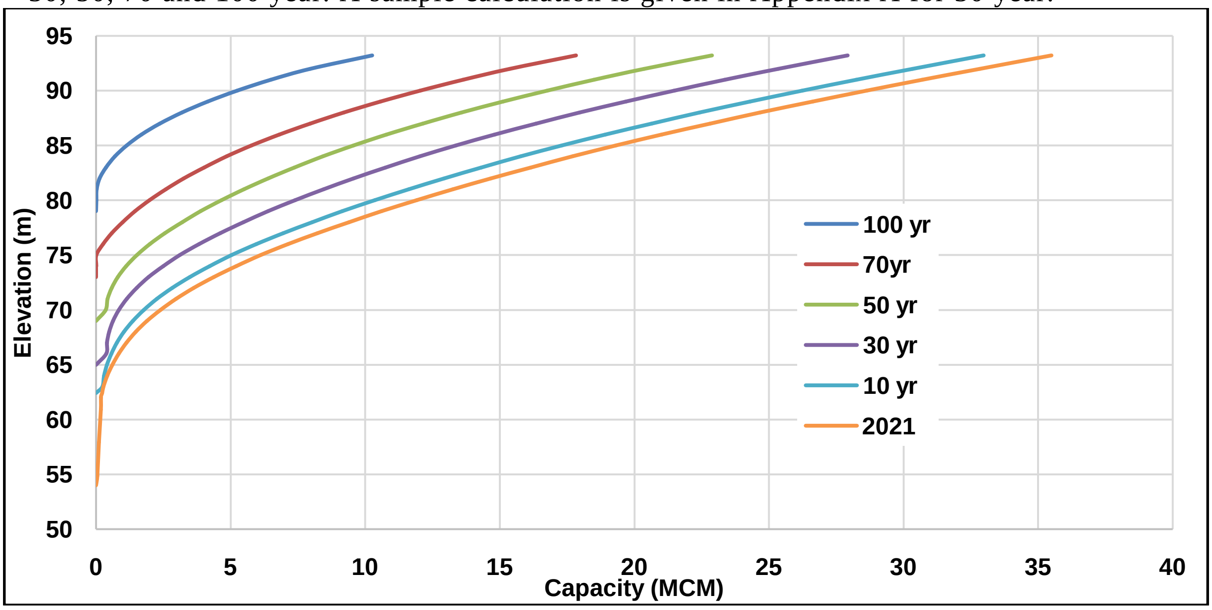

Figure 23-Elevation-capacity curve for different year for Anjunem Reservoir

Table 9-Elevation-capacity for different year for Anjunem Reservoir

Elevation (m)	Capacity (MCM)					
	2021	10yr	30yr	50yr	70yr	100yr
93.200	35.494	32.971	27.924	22.878	17.831	10.262
92.000	32.828	30.331	25.341	20.357	15.375	7.954
91.000	30.691	28.243	23.360	18.494	13.633	6.493
90.000	28.624	26.236	21.480	16.756	12.040	5.236
89.000	26.622	24.300	19.688	15.123	10.570	4.143
88.000	24.680	22.431	17.975	13.582	9.206	3.190
87.000	22.806	20.633	16.344	12.135	7.947	2.368
86.000	21.020	18.928	14.813	10.797	6.807	1.687
85.000	19.319	17.312	13.378	9.563	5.779	1.136
84.000	17.699	15.778	12.031	8.423	4.852	0.702
83.000	16.149	14.317	10.762	7.367	4.014	0.369
82.000	14.668	12.927	9.569	6.391	3.260	0.132
81.000	13.256	11.607	8.448	5.491	2.587	0.020
80.000	11.904	10.349	7.392	4.659	1.984	0.010
79.000	10.613	9.152	6.399	3.891	1.447	0.000
78.000	9.386	8.020	5.472	3.191	0.980	
77.000	8.225	6.955	4.612	2.559	0.582	
76.000	7.135	5.959	3.823	1.998	0.254	
75.000	6.124	5.044	3.113	1.515	0.004	
74.000	5.202	4.216	2.490	1.118	0.002	
73.000	4.368	3.476	1.953	0.806	0.000	
72.000	3.623	2.824	1.502	0.577		
71.000	2.965	2.258	1.134	0.430		
70.000	2.387	1.771	0.843	0.355		
69.000	1.892	1.365	0.629	0.000		

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Elevation (m)	Capacity (MCM)					
	2021	10yr	30yr	50yr	70yr	100yr
68.000	1.474	1.034	0.486			
67.000	1.125	0.770	0.406			
66.000	0.837	0.565	0.379			
65.000	0.599	0.407	0.000			
64.000	0.410	0.295				
63.000	0.274	0.233				
62.428	0.219	0.000				
62.000	0.180					
60.910	0.175					
57.910	0.100					
54.860	0.040					
54.000	0.000					

- **<u>Original Allotted Capacity in the Year of 1984:-</u>**

Original Capacity Survey:-

As per the sedimentation survey of 1984, original allocated capacity computed of 36344.27 acre feet (44.83 MCM). Up to elevation 305.77 ft (93.2 m.). Hence the total original allocated capacity was established in the year 1984 as 36344.27 acre feet (44.83 MCM).

Storage level	El-From-To	Original Allocated Capacity (MCM)	Original Allocated Capacity (ACRE FT)
Dead Storage	(Upto El. 203.41 Ft.) (62.00 m)	0.8	648.57
Live Storage	(El.203.41 – 305.77 Ft.) (62.00 m -93.2 m.)	44.03	35695.70
Total =		44.83	36344.27

- **<u>CAPACITY OF ANJUNEM DAM IN DIFFERENT SURVEY IN DIFFERENT ZONES:-</u>**

Capacity in Anjunem Dam in Different Years In Different zones			
(Capacity In ACRE FEET (MCM), Elevation in ft./m)			
ZONE	Dead Storage	Live Storage	Overall
YEAR	El. 203.41 Ft (62.00 m)	El. 203.41 – 305.77 Ft (62.00 – 93.2 m)	
1984	648.57 (0.8)	35695.70 (44.03)	36344.27 (44.83)
2021	137.82 (0.17)	28634.39 (35.32)	28772.21 (35.49)

Table-I

- **Inflow & Outflow at Anjunem Dam:-**

Year	Avg. Inflow (M-CUM)	Avg. Outflow (M-CUM)
2009	49.434	8.798
2010	64.2	21.8
2011	88.47	45.77
2012	91.25	65.7
2013	317.67	282.31
2014	88.61	41.46
2015	62.21	21.41
2016	78.34	16.65
2017	48.36	21.33
2018	50.75	23.19
2019	90.26	40.89
2020	114.58	105.52

Table-I A

- **Peak Flow at Anjunem Dam:-**

Anjunem Dam				
Peak flow of the Dam				
Sr. No.	Year	Date	Peak flow in Cumecs	Remarks
1	2009	19-Sep	98.72	
2	2010	24-Sep	50.20	
3	2011	3-Sep	78.97	
4	2012	1-Sep	57.44	
5	2013	18-Aug	46.77	
6	2014	10-Oct	61.32	
7	2015		0.00	No flood discharge during this monsoon season.
8	2016	10-Oct	71.36	
9	2017	18-Sep	35.09	
10	2018	27-Aug	9.28	
11	2019	2-Sep	49.40	
12	2020	21-Sep	50.32	

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Table-I B

- **Dam Level of Anjunem Dam in different year:-**

Year	Min. Dam Level (m)	Max. Dam Level (m)
2008	72.72	93.2
2009	67.63	93.24
2010	66.14	93.37
2011	73.87	93.26
2012	65.56	93.35
2013	67.43	93.35
2014	66.05	93.36
2015	64.2	91.1
2016	71.77	93.41
2017	71.21	93.28
2018	71.12	92.92
2019	67.48	93.35
2020	69.07	93.28

Table 10-Dam Level of Anjunem Dam

- **Minimum & Maximum water level in the year 2021:-**

Sl. No	Date	Minimum W.L (m)	Maximum W.L (m)
1	07.02.2021	87.44	87.51

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- **Elevation with Capacity for the year 2004 - 2020:-**

Anjunem Dam				
Elevation with capacity for the year 2004 to 2020				
Sr. No.	Year	Date	Dam Elevation (m)	Capacity in Ha. M.
1	2004	31-Aug	93.22	4491.60
2	2005	14-Aug	93.22	4491.60
3	2006	21-Sep	93.20	4483.00
4	2007	24-Sep	93.20	4483.00
5	2008	28-Sep	93.20	4483.00
6	2009	12-Sep	93.24	4500.20
7	2010	18-Oct	93.23	4495.90
8	2011	16-Oct	93.24	4500.20
9	2012	4-Oct	93.26	4508.80
10	2013	16-Oct	93.26	4508.80
11	2014	16-Oct	93.28	4517.40
12	2015	24-Oct	92.10	3944.00
13	2016	25-Oct	93.22	4491.60
14	2017	7-Oct	93.23	4495.90
15	2018	10-Oct	92.92	4390.00
16	2019	13-Oct	93.27	4513.10
17	2020	18-Oct	92.24	4500.20

Table-II

CAPACITY OF ANJUNEM DAM FOR DIFFERENT YEAR:-

Capacity of Anjunem Dam (Acre ft, MCM) was computed up to E.l. 305.77 ft. (93.2 m). The Below table shows Dam capacity at 3 feet (1m) depth interval in different year as here under:-

YEAR		1984			2021		
Elevation ft above M.S.L	Elevation mtr above M.S.L	Capacity in Acre Ft	Capacity in Hectare meter	Capacity in MCM	Capacity in Acre Ft	Capacity in Hectare meter	Capacity in MCM
177.17	54.00	0.00	0.00	0.00	0.00	0.0	0.00
179.99	54.86	139.28	17.18	0.17	32.43	4.0	0.04
189.99	57.91	324.29	40.00	0.40	81.07	10.0	0.10
199.84	60.91	648.57	80.00	0.80	141.63	17.5	0.17
203.74	62.10	668.84	82.50	0.83	145.93	18.0	0.18
206.69	63.00	851.25	105.00	1.05	222.25	27.4	0.27
209.97	64.00	1094.46	135.00	1.35	332.78	41.0	0.41
213.25	65.00	1337.68	165.00	1.65	485.96	59.9	0.60

YEAR		1984			2021		
Elevation ft above M.S.L	Elevation mtr above M.S.L	Capacity in Acre Ft	Capacity in Hectare meter	Capacity in MCM	Capacity in Acre Ft	Capacity in Hectare meter	Capacity in MCM
216.54	66.00	1621.43	200.00	2.00	678.69	83.7	0.84
219.82	67.00	1905.18	235.00	2.35	911.99	112.5	1.12
223.10	68.00	2270.00	280.00	2.80	1194.69	147.4	1.47
226.38	69.00	2691.57	332.00	3.32	1534.21	189.2	1.89
229.66	70.00	3178.00	392.00	3.92	1935.37	238.7	2.39
232.94	71.00	3786.03	467.00	4.67	2403.52	296.5	2.96
236.22	72.00	4580.53	565.00	5.65	2936.87	362.3	3.62
239.50	73.00	5391.24	665.00	6.65	3540.96	436.8	4.37
242.78	74.00	6242.49	770.00	7.70	4217.49	520.2	5.20
246.06	75.00	7255.88	895.00	8.95	4964.78	612.4	6.12
249.34	76.00	8269.27	1020.00	10.20	5784.29	713.5	7.13
252.62	77.00	9388.06	1158.00	11.58	6668.49	822.5	8.23
255.91	78.00	10539.27	1300.00	13.00	7609.19	938.6	9.39
259.19	79.00	11836.41	1460.00	14.60	8603.94	1061.3	10.61
262.47	80.00	13303.80	1641.00	16.41	9651.06	1190.4	11.90
265.75	81.00	14876.59	1835.00	18.35	10746.90	1325.6	13.26
269.03	82.00	16498.01	2035.00	20.35	11891.71	1466.8	14.67
272.31	83.00	18135.65	2237.00	22.37	13092.09	1614.9	16.15
275.59	84.00	19862.47	2450.00	24.50	14348.62	1769.9	17.70
278.87	85.00	21483.90	2650.00	26.50	15662.57	1931.9	19.32
282.15	86.00	23105.33	2850.00	28.50	17041.12	2102.0	21.02
285.43	87.00	24807.82	3060.00	30.60	18489.28	2280.6	22.81
288.71	88.00	26567.07	3277.00	32.77	20008.68	2468.0	24.68
291.99	89.00	28374.96	3500.00	35.00	21582.52	2662.2	26.62
295.28	90.00	30239.60	3730.00	37.30	23205.80	2862.4	28.62
298.56	91.00	31779.96	3920.00	39.20	24881.31	3069.1	30.69
301.84	92.00	33725.67	4160.00	41.60	26614.23	3282.8	32.83
305.12	93.00	35752.45	4410.00	44.10	28409.25	3504.2	35.04
305.77	93.20	36344.27	4483.00	44.83	28775.43	3549.4	35.49

Table 11- Capacity of Anjunem Dam at 3 feet (1 mtr)

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Table-III

Capacity Table –Anjunem Dam, 2021 (Pre-Monsoon):-

The Elevation with capacity table of Anjunem Dam 2021 has been computed by the **Average end area formula**; that is equal to -

$h/2\ (A_1+A_2) = V$ (as per I.S. 5477 part-II-1994**)**

Where

h = the height of the segment (Contour interval)

A_1 and A_2=the contour area at the end of the segment and

V = the volume of the segment (Volume between two consecutive contour)

The Capacity have been shown at 01 feet (0.3 m) depth interval by interpolation as tabulated here under :-

Elevation	Elevation	Capacity in	Capacity	Elevation	Elevation	Capacity in	Capacity	Elevation	Elevation	Capacity in	Capacity
In Ft,	In m.	Acre Ft.	In MCM	In Ft,	In m.	Acre Ft.	In MCM	In Ft,	In m.	Acre Ft.	In MCM
184	56.0	0	0	232	70.7	2253.783	2.78	280	85.4	16206.157	19.99
185	56.3	0	0	233	71.0	2399.711	2.96	281	85.7	16619.620	20.5
186	56.6	0	0	234	71.3	2553.747	3.15	282	86.0	17041.191	21.02
187	56.9	0	0	235	71.6	2715.889	3.35	283	86.3	17470.869	21.55
188	57.2	0	0	236	71.9	2878.032	3.55	284	86.6	17900.547	22.08
189	57.5	0	0	237	72.2	3048.282	3.76	285	86.9	18338.332	22.62
190	57.8	8.107	0.01	238	72.5	3226.638	3.98	286	87.2	18784.224	23.17
191	58.1	8.107	0.01	239	72.8	3413.102	4.21	287	87.5	19238.224	23.73
192	58.4	8.107	0.01	240	73.0	3542.817	4.37	288	87.8	19700.33	24.3
193	58.7	16.214	0.02	241	73.4	3802.245	4.69	289	88.0	20008.401	24.68
194	59.0	16.214	0.02	242	73.7	4004.923	4.94	290	88.4	20632.650	25.45
195	59.3	24.321	0.03	243	74.0	4215.708	5.2	291	88.7	21102.864	26.03
196	59.6	24.321	0.03	244	74.3	4434.601	5.47	292	89.0	21581.185	26.62
197	59.9	32.428	0.04	245	74.6	4661.601	5.75	293	89.3	22067.613	27.22
198	60.2	48.643	0.06	246	74.9	4888.600	6.03	294	89.6	22554.041	27.82
199	60.8	72.964	0.09	247	75.2	5123.707	6.32	295	89.9	23040.469	28.42
200	61.0	81.071	0.1	248	75.5	5366.921	6.62	296	90.2	23535.004	29.03
201	61.4	105.393	0.13	249	75.8	5618.242	6.93	297	90.5	24037.646	29.65
202	61.7	121.607	0.15	250	76.1	5869.563	7.24	298	90.8	24540.288	30.27
203	**62.0**	137.821	0.17	251	76.4	6128.992	7.56	299	91.0	24880.787	30.69
204	62.3	162.143	0.20	252	76.7	6396.527	7.89	300	91.4	25569.894	31.54
205	62.6	186.464	0.23	253	77.0	6672.169	8.23	301	91.7	26088.750	32.18
206	62.9	210.785	0.26	254	77.3	6947.812	8.57	302	92.0	26615.714	32.83
207	63.0	218.893	0.27	255	77.6	7223.454	8.91	303	92.3	27142.677	33.48
208	63.5	275.642	0.34	256	77.9	7515.311	9.27	304	92.6	27685.855	34.15
209	63.8	308.071	0.38	257	78.2	7807.168	9.63	305	92.9	28229.033	34.82
210	64.0	332.392	0.41	258	78.5	8099.025	9.99	306	93.2	28772.210	**35.49**
211	64.4	389.142	0.48	259	78.8	8398.988	10.36				
212	64.7	437.785	0.54	260	79.1	8707.059	10.74				
213	65.0	486.428	0.60	261	79.7	9331.308	11.51				
214	65.3	543.178	0.67	262	80.0	9647.487	11.9				
215	65.6	599.928	0.74	263	80.3	9971.772	12.3				
216	65.9	656.678	0.81	264	80.6	10304.165	12.71				
217	66.0	680.999	0.84	265	80.9	10636.557	13.12				
218	66.5	786.392	0.97	266	81.0	10750.057	13.26				
219	66.8	859.356	1.06	267	81.5	11309.449	13.95				
220	67.0	907.999	1.12	268	81.8	11658.056	14.38				
221	67.4	1021.499	1.26	269	82.0	11893.162	14.67				
222	67.7	1102.57	1.36	270	82.4	12363.376	15.25				
223	68.0	1191.748	1.47	271	82.7	12728.197	15.7				
224	68.3	289.034	1.59	272	83.0	13093.0179	16.15				
225	68.6	1394.427	1.72	273	83.3	13465.946	16.61				
226	68.9	1499.819	1.85	274	83.6	13838.874	17.07				
227	69.2	1605.212	1.98	275	83.9	14219.909	17.54				
228	69.5	1726.819	2.13	276	84.0	14349.623	17.7				
229	69.8	1848.426	2.28	277	84.5	14998.194	18.5				
230	70.0	1937.605	2.39	278	84.8	15395.443	18.99				
231	70.4	2115.961	2.61	279	85.0	15662.979	19.32				

Table 12-Capacity of Anjunem dam at 01 feet depth interval

ESTIMATION OF SEDIMENTATION IN DIFFERENT ZONES OF DAM (iii)

This section has been analyzed loss of storage capacity, rate of sedimentation in each vertical zone separately viz. dead storage, live storage and flood storage etc.

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Table-IV

Loss of Storage Capacity in Anjunem Dam

Period	No. of years	Total volume of Loss of Capacity		Average Annual loss of Capacity	
		Acre Feet	10^6 m^3	Acre Feet	10^6 m^3
1984-2021	37	7572.06	9	205	0.25

Table-V

Having taken the Drainage area of Anjunem Dam = 6.63 Sq, Miles (17.18 Sq. Km) upto the dam area.

Sediment Deposition Rate in Anjunem Dam

Between Years	No. of years	Volume of Deposit		Sediment Deposition Rate	
		Acre feet	MM^3	Aft./Sq. mile/year	M3/Sq km/year
1984-2021	37	7572.06	9.34	30.86	14693

Table-VI

- **Loss of Sedimentation in different zone i.e. Flood, Dead and Live zone between the year 1984 and 2021:-**

EL IN M.	CAP IN MCM		CAP-LOSS 1997-2020
	1984	2021	
93.20	44.83	35.49	9.34
93.00	44.10	35.04	9.06
92.00	41.60	32.83	8.77
91.00	39.20	30.69	8.51
90.00	37.30	28.62	8.68
89.00	35.00	26.62	8.38
88.00	32.77	24.68	8.09
87.00	30.60	22.81	7.79
86.00	28.50	21.02	7.48
85.00	26.50	19.32	7.18
84.00	24.50	17.70	6.80
83.00	22.37	16.15	6.22
82.00	20.35	14.67	5.68
81.00	18.35	13.26	5.09
80.00	16.41	11.90	4.51
79.00	14.60	10.61	3.99
78.00	13.00	9.39	3.61
77.00	11.58	8.23	3.35
76.00	10.20	7.13	3.07
75.00	8.95	6.12	2.83
74.00	7.70	5.20	2.50
73.00	6.65	4.37	2.28
72.00	5.65	3.62	2.03
71.00	4.67	2.96	1.71
70.00	3.92	2.39	1.53
69.00	3.32	1.89	1.43
68.00	2.80	1.47	1.33
67.00	2.35	1.12	1.23
66.00	2.00	0.84	1.16
65.00	1.65	0.60	1.05
64.00	1.35	0.41	0.94
63.00	1.05	0.27	0.78
62.10	0.83	0.18	0.65
62.00	0.83	0.17	0.65
60.91	0.80	0.10	0.70
57.91	0.40	0.04	0.36
54.00	0.00	0.00	0.00

LOSS OF CAP IN LIVE ZONE			
EL	93.2	62.0	LIVE CAP
YEAR	CAP IN MCM		
1984	44.830	0.827	44.00
2021	35.494	0.175	35.32
LOSS OF CAP IN LIVE ZONE			**8.68**

LOSS OF CAP IN DEAD ZONE			
EL	62.0	54.0	CAPACITY
YEAR	CAP IN MCM		
1984	0.827	0.000	0.83
2021	0.175	0.000	0.17
LOSS OF CAP IN DEAD ZONE			**0.65**

Total loss of Capacity = 9.34 MCM

- **Graph of Loss of Capacity in the Year between 1984 and 2021:-**

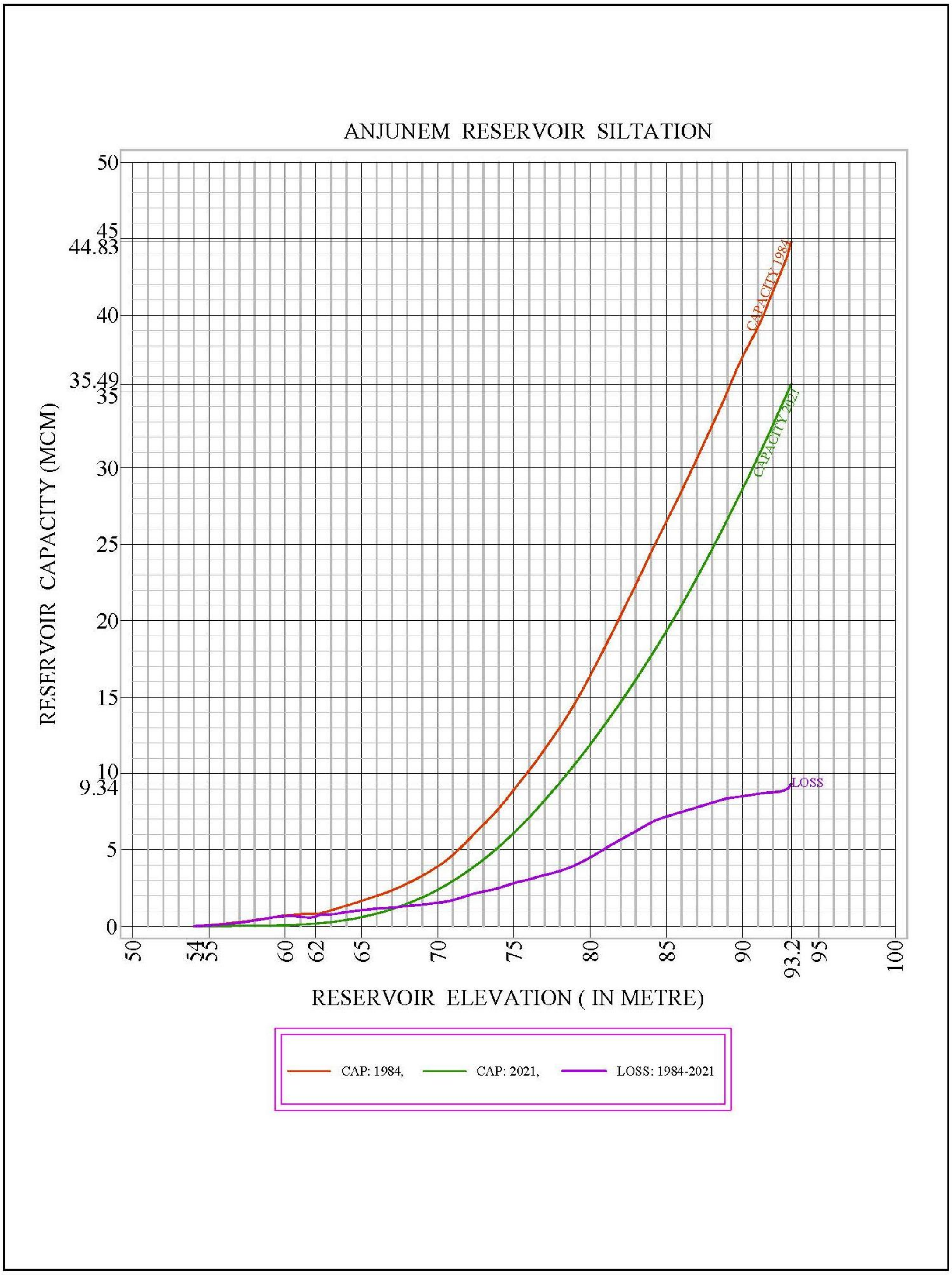

Figure 24-Graph of loss of Capacity in the year 1984 & 2021

Table-VII

Depth Wise location of Deposit in Percentage of Anjunem Dam

DEPTH WISE LOCATION OF DEPOSIT IN ANJUNEM DAM (PERCENTAGE OF TOTAL DEPOSIT)												
BETWEEN EL.(FT/M)	177-187 (54-57)	187-197 (57-60)	197-207 (60-64)	207-217 (64-66)	217-227 (66-70)	227-237 (70-72)	237-247 (72-75)	247-257 (75-78)	257-267 (78-81)	267-277 (81-84)	277-287 (84-87)	287-306 (87-93.2)
DEPTH (FT/M)	0-10 (0-3.0)	10-20 (3.0-6.1)	20-30 (6.1-9.1)	30-40 (9.1-12.2)	40-50 (12.2-15.2)	50-60 (15.2-18.3)	60-70 (18.3-21.3)	70-80 (21.3-24.4)	80-90 (24.4-27.4)	90-100 (27.4-31.1)	100-110 (31.1-33.5)	110-129 (33.5-39.3)
2021	0.0	0.0	1.0	1.0	4.0	4.0	8.0	10.0	11.0	13.0	14.0	34.0

Table 13- Depth wise location of deposit of Anjunem Dam

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- **Graph of Anjunem Dam sedimentation in the year 2021:-**

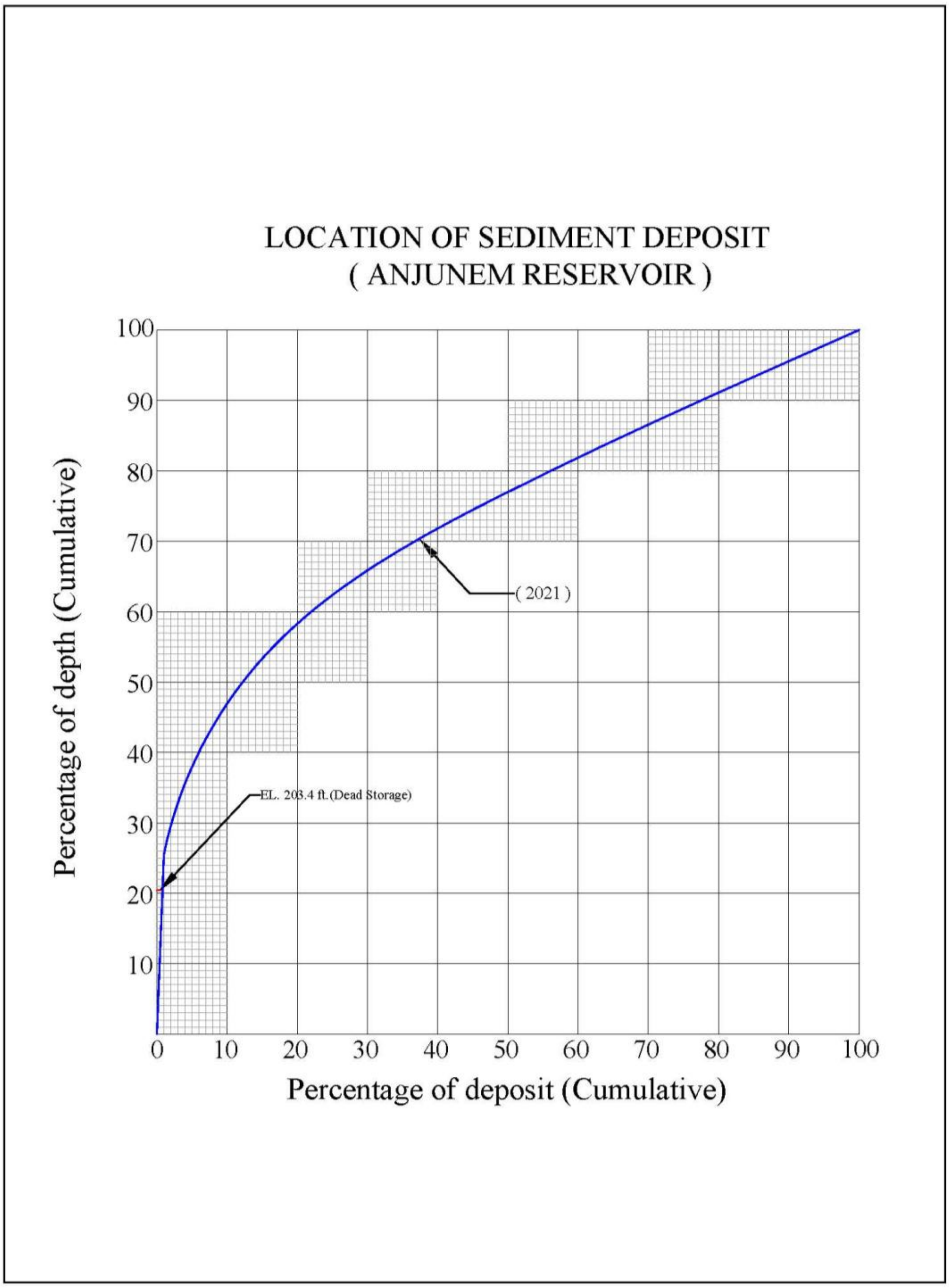

Figure 25- Graph of Depth wise sedimentation at Anjunem Dam

ANALYSIS OF BED MATERIAL SAMPLES (iv)

This section has been analyzed bed material samples to obtain sediment sizes, density, specific gravity, moisture content etc.

13.3 Analysis of bed Material Samples:-

1.0 Grain size analysis (As per IS: 2720 (Part-4)-1985)

The grain size distributions of all representative samples were determined from sieve analysis and hydrometer analysis upon the average grain diameter of the soil samples. The higher grained samples like sand, gravel were analyzed through sieve hydrometer analysis depending upon the average grain diameter of the soil samples. The higher grained samples like sand were analyzed through sieve and the lower grain samples like fine silt and clay were analyzed through hydrometer. The results have been presented in the tables and graphs.

2.0 Natural Moisture Content (NMC) (As per IS: 2720 (Part-1)-1983)

In almost all soil tests natural moisture content of the soil is to be determined. The knowledge of the natural moisture content is essential in all studies of soil mechanics. To sight a few, natural moisture content is used in determining the bearing capacity and settlement. The natural moisture content will give an idea of the state of soil in the field.

3.0 Specific Gravity (As per IS: 2720 (Part-3/ sec-1)-1980)

This test has been carried out to determine the specific gravity of fine-grained soil by density bottle method as per IS: 2720 (Part III/Sec 1) –1980. Specific gravity is the ratio of the weight in air of a given volume of a material at a standard temperature to the weight in air of equal volume of distilled water at the same stated temperature.

13.3.1 Soil Sample Positions:-

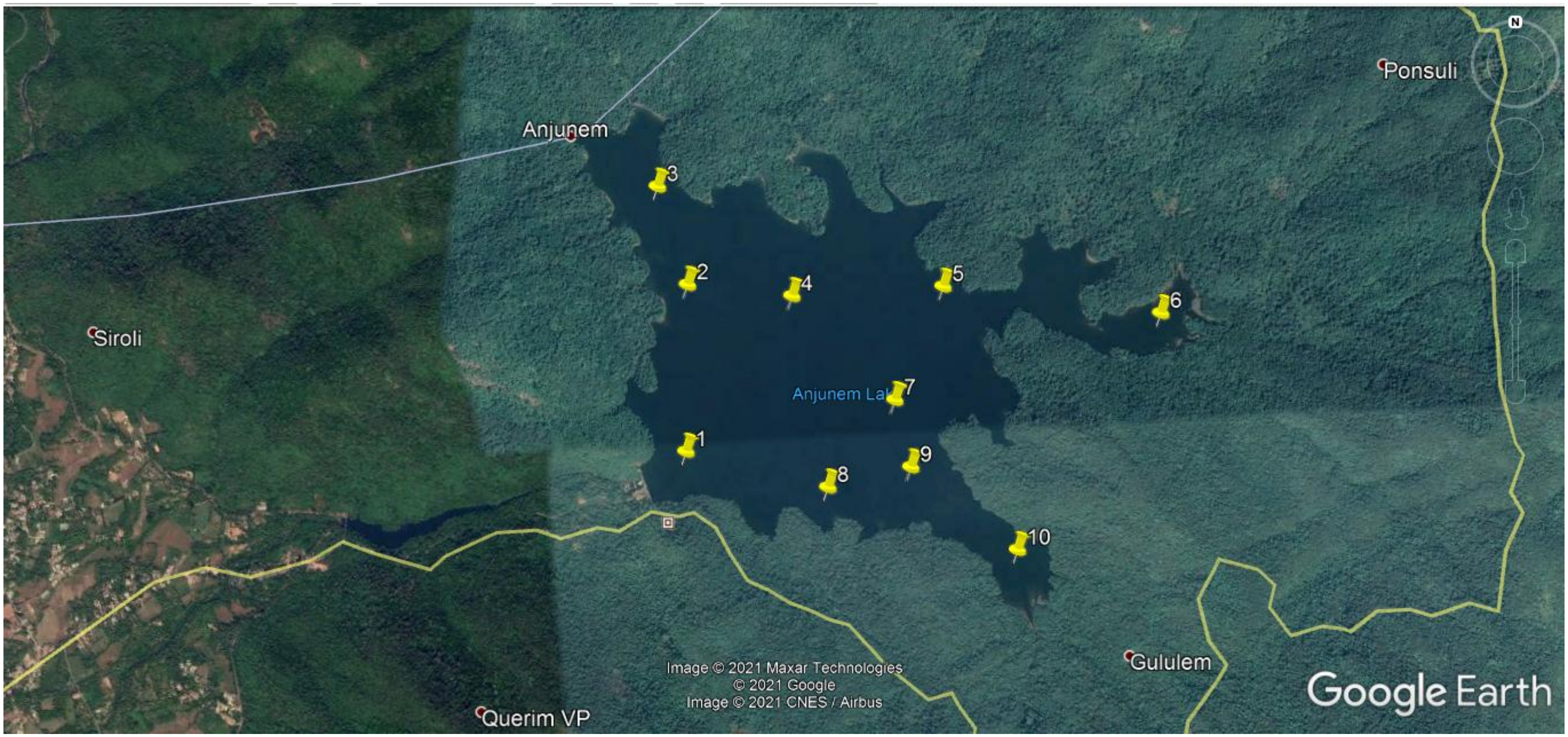

Figure 26-Locations of Soil Samples

13.3.2 Sediment Size, Density, Specific Gravity and Moisture Content:-

SITE: ANJUNEM DAM											
TEST RESULTS											
Sl. No.	Sample No.	Latitude (N)	Longitude (E)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Moisture Content (%)	Specific Gravity	Uniformity of soil
1	1	15˚37'2.58"	74°5'23.73"	Deep brownish, clayey silt mixed with high percentage of sand	0.90	23.00	60.00	16.10	79.35	2.642	Non-uniform
2	2	15˚37'24.05"	74°5'23.93"	Deep brownish, clayey silt mixed with high percentage of sand	0.00	19.70	61.36	18.94	68.90	2.632	Non-uniform
3	3	15˚37'36.67"	74°5'19.91"	Deep brownish, clayey silt mixed with high percentage of sand	0.00	21.00	59.80	19.20	72.10	2.635	Uniform
4	4	15˚37'22.59"	74°5'37.90"	Deep brownish, clayey silt mixed with high percentage of sand	0.67	25.00	56.73	17.60	65.70	2.640	Non-uniform
5	5	15˚37'23.81"	74°5'58.11"	Deep brownish, clayey silt mixed with high percentage of sand	0.00	16.80	62.40	20.80	71.50	2.628	Uniform
6	6	15˚37'20.39"	74°6'27.23"	Deep brownish, clayey silt mixed with high percentage of sand	1.00	21.00	60.40	17.60	73.20	2.635	Non-uniform
7	7	15˚37'9.22"	74°5'51.66"	Deep brownish, clayey silt mixed with high percentage of sand	0.00	26.50	51.10	22.40	69.70	2.639	Non-uniform
8	8	15˚36'57.99"	74°5'42.71"	Deep brownish, clayey silt mixed with high percentage of sand	0.00	31.00	48.20	20.80	68.00	2.640	Uniform
9	9	15˚37'0.59"	74°5'53.81"	Deep brownish, clayey silt mixed with high percentage of sand	0.00	23.00	57.80	19.20	70.00	2.632	Uniform
10	10	15˚36'49.95"	74°6'8.07"	Deep brownish, clayey silt mixed with high percentage of sand	0.00	18.00	58.00	24.00	71.60	2.630	Non-uniform

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13.3.3 Bulk Density of the samples:-

Sample - 1

		Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	23.90					
Silt (%)	60.00					
Clay (%)	16.10	Cont. Submerged	256	91	0	0.96
		Periodic drwadown	135	29	0	0.39
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	1013.83	1013.99	1014.10	1014.18	1014.2	1014.30	1014.11	1014.28	1014.40	1014.50	1014.57
Periodic drwadown	1049.17	1049.24	1049.28	1049.32	1049.3	1049.37	1049.29	1049.36	1049.41	1049.44	1049.48
Resvr. normally empty	1068.05	1068.05	1068.05	1068.05	1068.1	1068.05	1068.05	1068.05	1068.05	1068.05	1068.05

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 2

Sand (%)	19.70	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	61.36					
Clay (%)	18.94	Cont. Submerged	256	91	0	1.04
		Periodic drwadown	135	29	0	0.43
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	992.57	992.75	992.87	992.96	993.03	993.09	992.89	993.07	993.20	993.30	993.38
Periodic drwadown	1032.31	1032.38	1032.43	1032.47	1032.5	1032.52	1032.44	1032.51	1032.57	1032.61	1032.64
Resvr. normally empty	1053.60	1053.60	1053.60	1053.60	1053.6	1053.60	1053.60	1053.60	1053.60	1053.60	1053.60

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

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Sample - 3

				B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	21.00		Reservoir condition:				
Silt (%)	59.80						
Clay (%)	19.20		Cont. Submerged	256	91	0	1.04
			Periodic drwadown	135	29	0	0.43
Total (%)	100.00		Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	991.13	991.31	991.42	991.51	991.59	991.65	991.44	991.63	991.76	991.86	991.94
Periodic drwadown	1030.93	1031.00	1031.05	1031.09	1031.1	1031.15	1031.06	1031.14	1031.19	1031.23	1031.27
Resvr. normally empty	1052.27	1052.27	1052.27	1052.27	1052.3	1052.27	1052.27	1052.27	1052.27	1052.27	1052.27

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

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Sample - 4

Sand (%)	25.67	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	56.73					
Clay (%)	17.60	Cont. Submerged	256	91	0	0.97
		Periodic drwadown	135	29	0	0.40
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	1003.80	1003.96	1004.07	1004.15	1004.2	1004.28	1004.09	1004.26	1004.38	1004.47	1004.55
Periodic drwadown	1040.66	1040.73	1040.78	1040.81	1040.8	1040.86	1040.78	1040.85	1040.91	1040.94	1040.98
Resvr. normally empty	1060.42	1060.42	1060.42	1060.42	1060.4	1060.42	1060.42	1060.42	1060.42	1060.42	1060.42

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 5

Sand (%)	16.80	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	62.40					
Clay (%)	20.80	Cont. Submerged	256	91	0	1.10
		Periodic drwadown	135	29	0	0.46
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	978.61	978.79	978.92	979.01	979.09	979.16	978.94	979.13	979.27	979.38	979.46
Periodic drwadown	1021.25	1021.33	1021.38	1021.42	1021.5	1021.48	1021.39	1021.47	1021.53	1021.57	1021.61
Resvr. normally empty	1044.13	1044.13	1044.13	1044.13	1044.1	1044.13	1044.13	1044.13	1044.13	1044.13	1044.13

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

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Sample - 6

				B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	22.00	Reservoir condition:					
Silt (%)	60.40						
Clay (%)	17.60	Cont. Submerged		256	91	0	1.00
		Periodic drwadown		135	29	0	0.41
Total (%)	100.00	Resvr. normally empty		0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	1002.70	1002.86	1002.98	1003.06	1003.1	1003.20	1003.00	1003.17	1003.30	1003.40	1003.47
Periodic drwadown	1040.30	1040.37	1040.41	1040.45	1040.5	1040.50	1040.42	1040.49	1040.54	1040.58	1040.62
Resvr. normally empty	1060.42	1060.42	1060.42	1060.42	1060.4	1060.42	1060.42	1060.42	1060.42	1060.42	1060.42

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

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Sample - 7

		Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	26.50					
Silt (%)	51.10					
Clay (%)	22.40	Cont. Submerged	256	91	0	1.04
		Periodic drwadown	135	29	0	0.45
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	970.25	970.43	970.55	970.64	970.7	970.77	970.57	970.75	970.88	970.98	971.06
Periodic drwadown	1012.95	1013.03	1013.08	1013.12	1013.2	1013.18	1013.09	1013.17	1013.23	1013.27	1013.30
Resvr. normally empty	1035.98	1035.98	1035.98	1035.98	1036.0	1035.98	1035.98	1035.98	1035.98	1035.98	1035.98

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

Sample - 8

Sand (%)	31.00	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	48.20					
Clay (%)	20.80	Cont. Submerged	256	91	0	0.97
		Periodic drwadown	135	29	0	0.42
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	982.87	983.03	983.14	983.23	983.3	983.35	983.16	983.33	983.45	983.55	983.62
Periodic drwadown	1022.67	1022.74	1022.79	1022.82	1022.9	1022.88	1022.79	1022.87	1022.92	1022.96	1023.00
Resvr. normally empty	1044.13	1044.13	1044.13	1044.13	1044.1	1044.13	1044.13	1044.13	1044.13	1044.13	1044.13

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

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Sample - 9

		Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	23.00					
Silt (%)	57.80					
Clay (%)	19.20	Cont. Submerged	256	91	0	1.02
		Periodic drwadown	135	29	0	0.43
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	991.73	991.90	992.02	992.11	992.2	992.24	992.04	992.22	992.34	992.44	992.52
Periodic drwadown	1031.13	1031.20	1031.25	1031.29	1031.3	1031.35	1031.26	1031.34	1031.39	1031.43	1031.46
Resvr. normally empty	1052.27	1052.27	1052.27	1052.27	1052.3	1052.27	1052.27	1052.27	1052.27	1052.27	1052.27

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

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Sample - 10

		Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	18.00					
Silt (%)	58.00					
Clay (%)	24.00	Cont. Submerged	256	91	0	1.14
		Periodic drwadown	135	29	0	0.49
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	956.44	956.63	956.76	956.86	956.9	957.01	956.78	956.98	957.13	957.24	957.33
Periodic drwadown	1002.84	1002.92	1002.98	1003.02	1003.1	1003.09	1002.99	1003.07	1003.14	1003.18	1003.22
Resvr. normally empty	1027.84	1027.84	1027.84	1027.84	1027.8	1027.84	1027.84	1027.84	1027.84	1027.84	1027.84

Where,

W1 = Intial bulk density of sediment in kg/m3
W2 = Bulk density of sediment after 2 yrs kg/m3.
W3 = Bulk density of sediment after 3 yrs kg/m3.
W4 = Bulk density of sediment after 4 yrs kg/m3.
W5 = Bulk density of sediment after 5 yrs kg/m3.
W6 = Bulk density of sediment after 6 yrs kg/m3

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13.3.4 Kramer's Coefficient:-

Kramer's coefficient

% Finer	Dia (mm)	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5	Sample-6	Sample-7	Sample-8	Sample-9	Sample-10
0	D0	-	-		-	-	-	-	-	-	-
10	D10	-	-		-	-	-	-	-	-	-
20	D20	0.0037	0.0013	0.0038	0.005	-	0.0038	-	-	0.00379	-
30	D30	0.0080	0.0054	0.0075	0.011	0.0075	0.0080	0.0075	0.008	0.015	0.0045
40	D40	0.0170	0.0104	0.0146	0.0240	0.0250	0.0160	0.018	0.024	0.060	0.0160
50	D50	0.4100	0.0198	0.0279	0.0650	0.0670	0.0500	0.038	0.067	0.068	0.0520
60	D60	0.6800	0.0635	0.0670	0.0700	0.0690	0.0680	0.078	0.072	0.070	0.0660
70	D70	0.7200	0.0700	0.0700	0.0740	0.0720	0.0720	0.074	0.091	0.072	0.0700
80	D80	0.1400	0.0750	0.0800	0.1400	0.0750	0.1000	0.130	0.030	0.088	0.0740
90	D90	0.4100	0.1700	0.1500	0.4400	0.1700	0.3400	0.330	0.062	0.150	0.2400
100	D100	5.6000	4.7500	1.1800	5.6000	1.1800	5.6000	4.750	4.750	0.600	2.3600
84	D84	0.1560	0.1200	0.1000	0.1560	0.0800	0.1500	0.015	0.031	0.073	0.1000
16	D16	-	-	-	-	-	-	-	-	-	-

For Sample-1

Dia (mm)	For Sample-1	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20	0.004	20				
D30	0.008	30	10	0.005	0.054	-1.264
D40	0.017	40	10	0.012	0.117	-0.933
D50	0.410	50	10	0.083	0.835	-0.078
D60	0.680	60	10	0.528	5.280	0.723
D70	0.720	70	10	0.700	6.997	0.845
D80	0.140	80	10	0.317	3.175	0.502
D90	0.410	90	10	0.240	2.396	0.379
D100	5.600	100	10	1.515	15.153	1.180
D84	0.156	84				
D16	-	16				

da	0.425	mm
dg	1.085	mm
σg	-	
M	0.030	

Remarks: Sediment is non-uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-2

Dia (mm)	For Sample-2	p	Δp	di	dixΔp	log(dixΔp)
D0	-	0				
D10	-	10				
D20	0.001	20				
D30	0.005	30	10	0.003	0.026	-1.577
D40	0.010	40	10	0.007	0.075	-1.126
D50	0.020	50	10	0.014	0.143	-0.844
D60	0.064	60	10	0.035	0.355	-0.450
D70	0.070	70	10	0.067	0.667	-0.176
D80	0.075	80	10	0.072	0.725	-0.140
D90	0.170	90	10	0.113	1.129	0.053
D100	4.750	100	10	0.899	8.986	0.954
D84	0.120	84				
D16	-	16				

da	0.151	mm
dg	0.986	mm
σg	-	
M	0.021	

Remarks: Sediment is non-uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-3

Dia (mm)	For Sample-3	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10	0.000	10				
D20	0.004	20				
D30	0.007	30	10	0.005	0.053	-1.275
D40	0.015	40	10	0.010	0.105	-0.981
D50	0.028	50	10	0.020	0.202	-0.694
D60	0.067	60	10	0.043	0.432	-0.364
D70	0.070	70	10	0.068	0.685	-0.164
D80	0.080	80	10	0.075	0.748	-0.126
D90	0.150	90	10	0.110	1.095	0.040
D100	1.180	100	10	0.421	4.207	0.624
D84	0.100	84				
D16	-	16				

da	0.094	mm
dg	0.935	mm
σg	-	
M	0.050	

Remarks: Sediment is uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

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For Sample-4

Dia (mm)	For Sample-4	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10	-	10				
D20	0.005	20				
D30	0.011	30	10	0.008	0.075	-1.124
D40	0.024	40	10	0.016	0.159	-0.798
D50	0.065	50	10	0.039	0.395	-0.403
D60	0.070	60	10	0.067	0.675	-0.171
D70	0.074	70	10	0.072	0.720	-0.143
D80	0.140	80	10	0.102	1.018	0.008
D90	0.440	90	10	0.248	2.482	0.395
D100	5.600	100	10	1.570	15.697	1.196
D84	0.156	84				
D16	-	16				

da 0.2653 mm

dg 0.976 mm

σg -

M 0.031

Remarks: Sediment is non-uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

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For Sample-5

Dia (mm)	For Sample-5	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20	-	20				
D30	0.007	30				
D40	0.025	40	10	0.014	0.137	-0.865
D50	0.067	50	10	0.041	0.409	-0.388
D60	0.069	60	10	0.068	0.680	-0.168
D70	0.072	70	10	0.070	0.705	-0.152
D80	0.075	80	10	0.073	0.735	-0.134
D90	0.170	90	10	0.113	1.129	0.053
D100	1.180	100	10	0.448	4.479	0.651
D84	0.080	84				
D16	-	16				

da	0.118	mm
dg	0.977	mm
σg		
M	0.071	

Remarks: Sediment is uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

For Sample-6

Dia (mm)	For Sample-6	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10	-	10				
D20	0.004	20				
D30	0.008	30	10	0.006	0.055	-1.259
D40	0.016	40	10	0.011	0.113	-0.946
D50	0.050	50	10	0.028	0.283	-0.548
D60	0.068	60	10	0.058	0.583	-0.234
D70	0.072	70	10	0.070	0.700	-0.155
D80	0.100	80	10	0.085	0.849	-0.071
D90	0.340	90	10	0.184	1.844	0.266
D100	5.600	100	10	1.380	13.799	1.140
D84	0.150	84				
D16	-	16				

da	0.228	mm
dg	0.959	mm
σg		
M	0.025	

Remarks: Sediment is non -uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

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For Sample-7

Dia (mm)	For Sample-7	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20	-	20				
D30	0.007	30				
D40	0.018	40	10	0.012	0.116	-0.936
D50	0.038	50	10	0.026	0.262	-0.582
D60	0.078	60	10	0.054	0.544	-0.264
D70	0.074	70	10	0.076	0.760	-0.119
D80	0.130	80	10	0.098	0.981	-0.008
D90	0.330	90	10	0.207	2.071	0.316
D100	4.750	100	10	1.252	12.520	1.098
D84	0.015	84				
D16	-	16				

da	0.246	mm
dg	0.989	mm
σg		
M	0.022	

Remarks: Sediment is non - uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

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For Sample-8

Dia (mm)	For Sample-8	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20	-	20				
D30	0.008	30				
D40	0.024	40	10	0.014	0.137	-0.864
D50	0.067	50	10	0.040	0.401	-0.397
D60	0.072	60	10	0.069	0.695	-0.158
D70	0.091	70	10	0.081	0.809	-0.092
D80	0.030	80	10	0.052	0.522	-0.282
D90	0.062	90	10	0.043	0.431	-0.365
D100	4.750	100	10	0.543	5.427	0.735
D84	0.031	84				
D16	-	16				

da	0.120	mm
dg	0.968	mm
σg		
M	0.068	

Remarks: Sediment is uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

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For Sample-9

Dia (mm)	For Sample-9	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10	-	10				
D20	0.004	20				
D30	0.015	30	10	0.008	0.075	-1.123
D40	0.060	40	10	0.030	0.300	-0.523
D50	0.068	50	10	0.064	0.639	-0.195
D60	0.070	60	10	0.069	0.690	-0.161
D70	0.072	70	10	0.071	0.710	-0.149
D80	0.088	80	10	0.080	0.796	-0.099
D90	0.150	90	10	0.115	1.149	0.060
D100	0.600	100	10	0.300	3.000	0.477
D84	0.073	84				
D16		16				

da	0.092	mm
dg	0.961	mm
σg		
M	0.160	

Remarks: Sediment is uniform

Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

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For Sample-10

Dia (mm)	For Sample-10	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10	-	10				
D20	-	20				
D30	0.0045	30				
D40	0.0160	40	10	0.008	0.085	-1.071
D50	0.0520	50	10	0.029	0.288	-0.540
D60	0.0660	60	10	0.059	0.586	-0.232
D70	0.0700	70	10	0.068	0.680	-0.168
D80	0.0740	80	10	0.072	0.720	-0.143
D90	0.2400	90	10	0.133	1.333	0.125
D100	2.3600	100	10	0.753	7.526	0.877
D84	0.1000	84				
D16	-	16				

da 0.160 mm

dg 0.974 mm

σg -

M 0.034

Remarks: Sediment is non - uniform

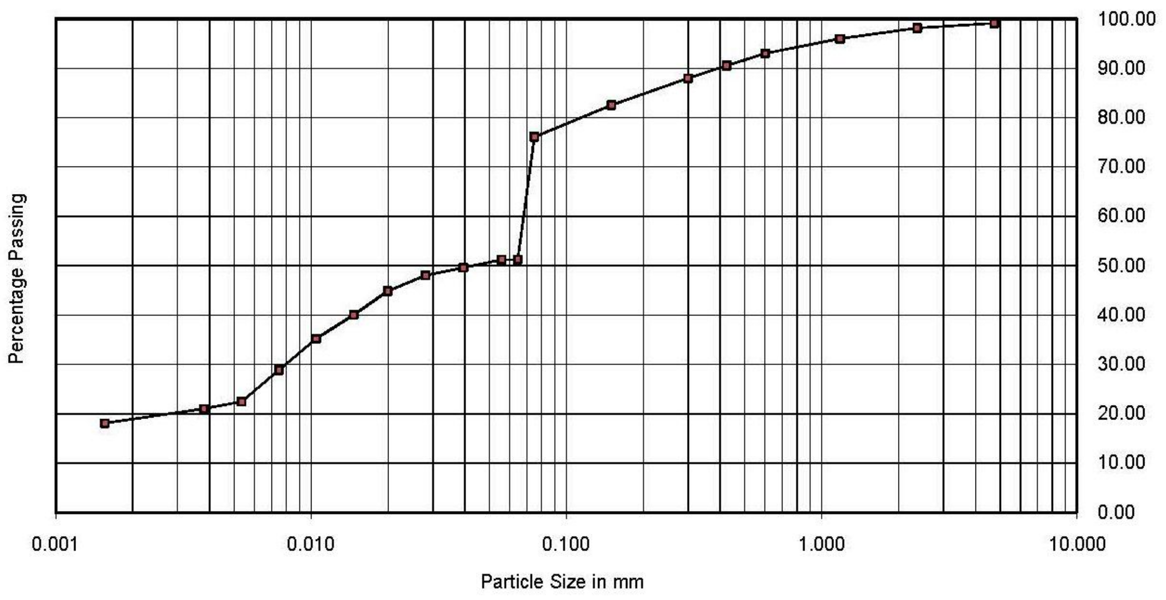
Where,

p = Percentage finer in %
da = Arithmetic mean size, mm
dg = Geometric mean size, mm
σg = Geometric standard deviation
M = Kramer's uniformity co-efficient

13.3.5 Grain Size Distribution curves:-

GRAIN SIZE DISTRIBUTION CURVES

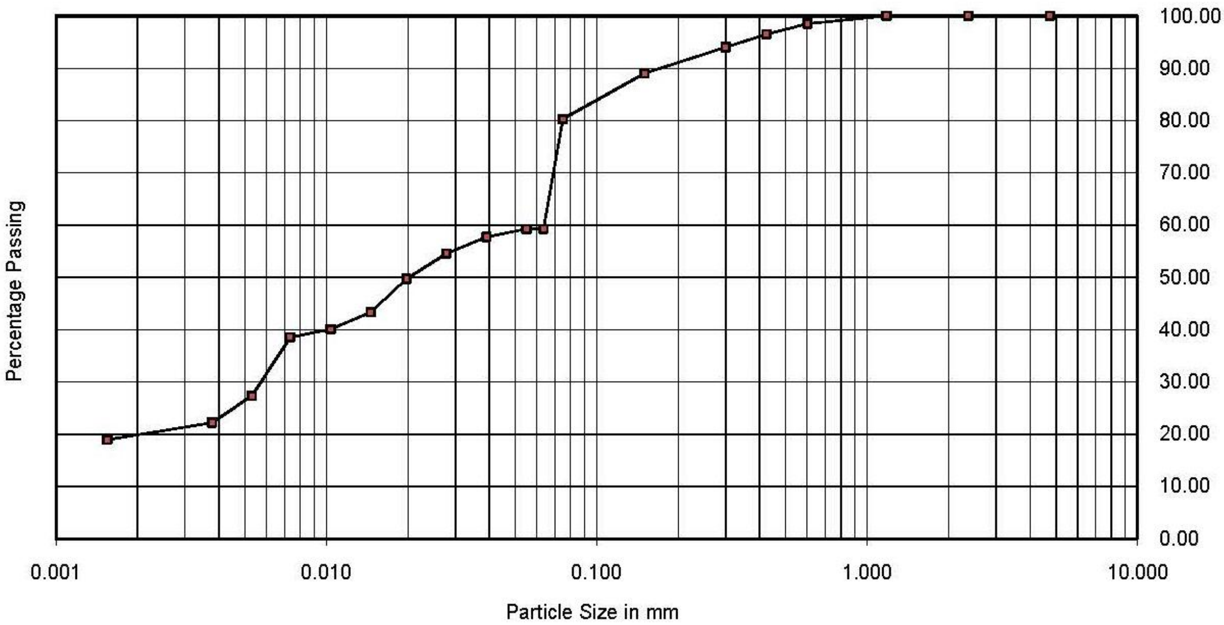
Site:	Anjunem Dam
Sample No.	1



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
1	18.10	57.96	23.04	0.90

GRAIN SIZE DISTRIBUTION CURVES

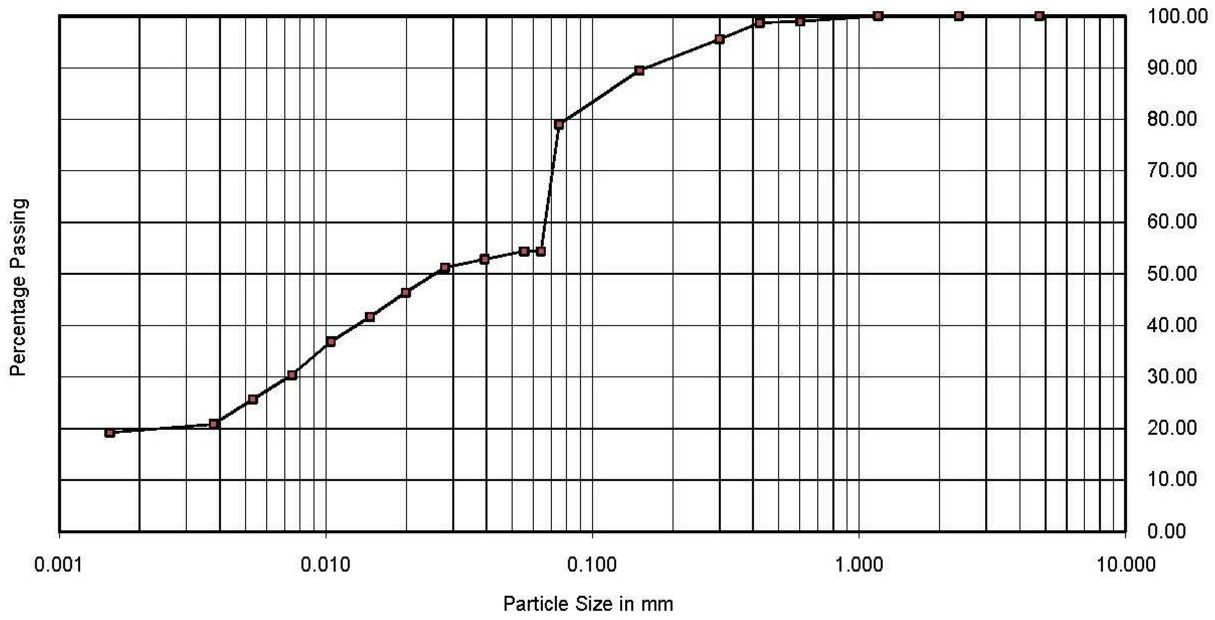
Site:	Anjunem Dam
Sample No.	2



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
2	18.94	61.36	19.7	0.00

GRAIN SIZE DISTRIBUTION CURVES

Site:	Anjunem Dam
Sample No.	3



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
3	19.20	59.80	21	0.00

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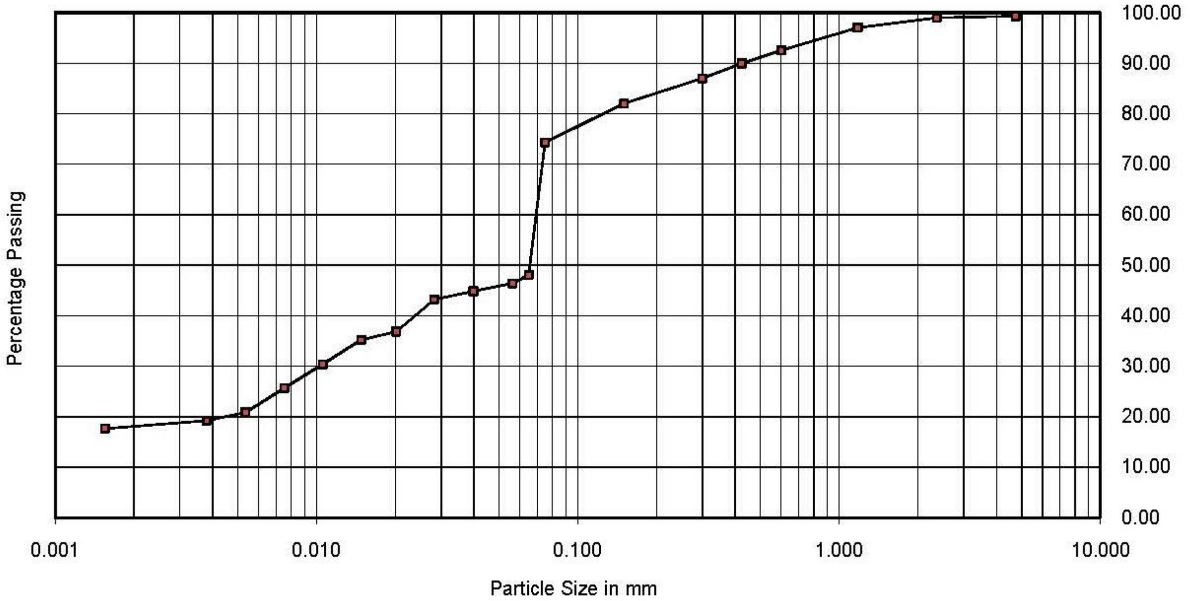
GRAIN SIZE DISTRIBUTION CURVES

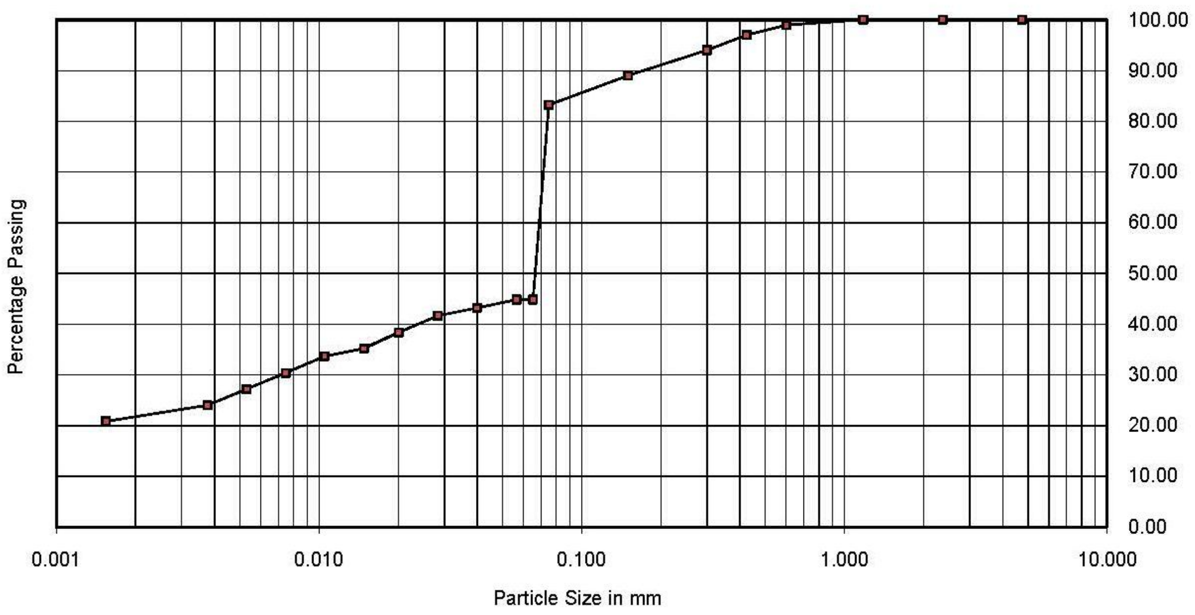
Site:	Anjunem Dam
Sample No.	4



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
4	17.60	56.73	25	0.67

GRAIN SIZE DISTRIBUTION CURVES

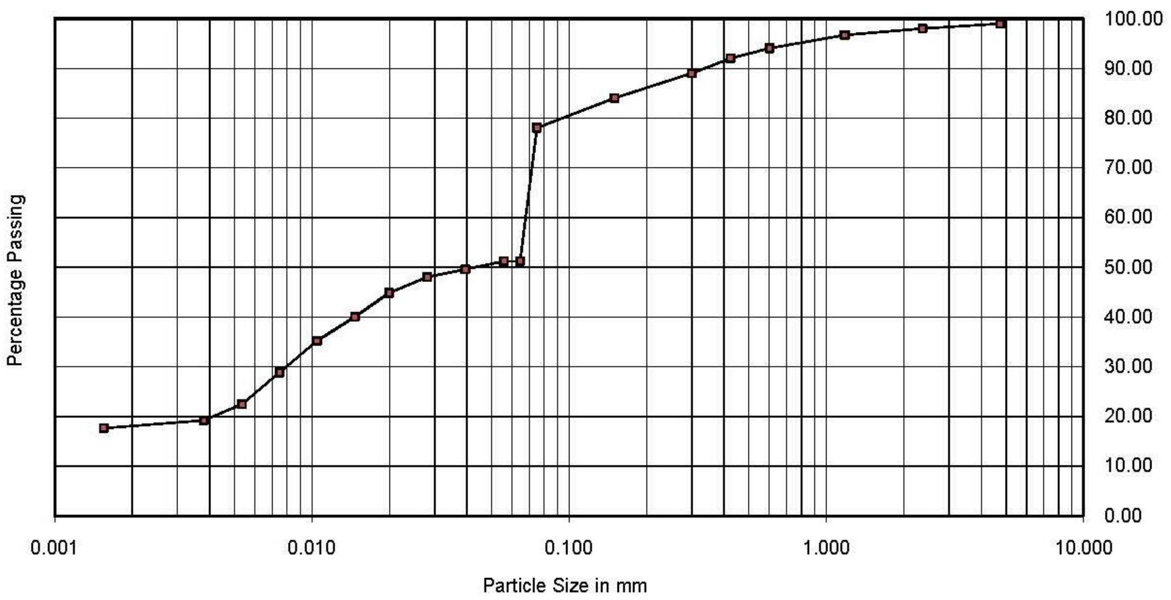
Site:	Anjunem Dam
Sample No.	5



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
5	20.80	62.40	16.8	0.00

GRAIN SIZE DISTRIBUTION CURVES

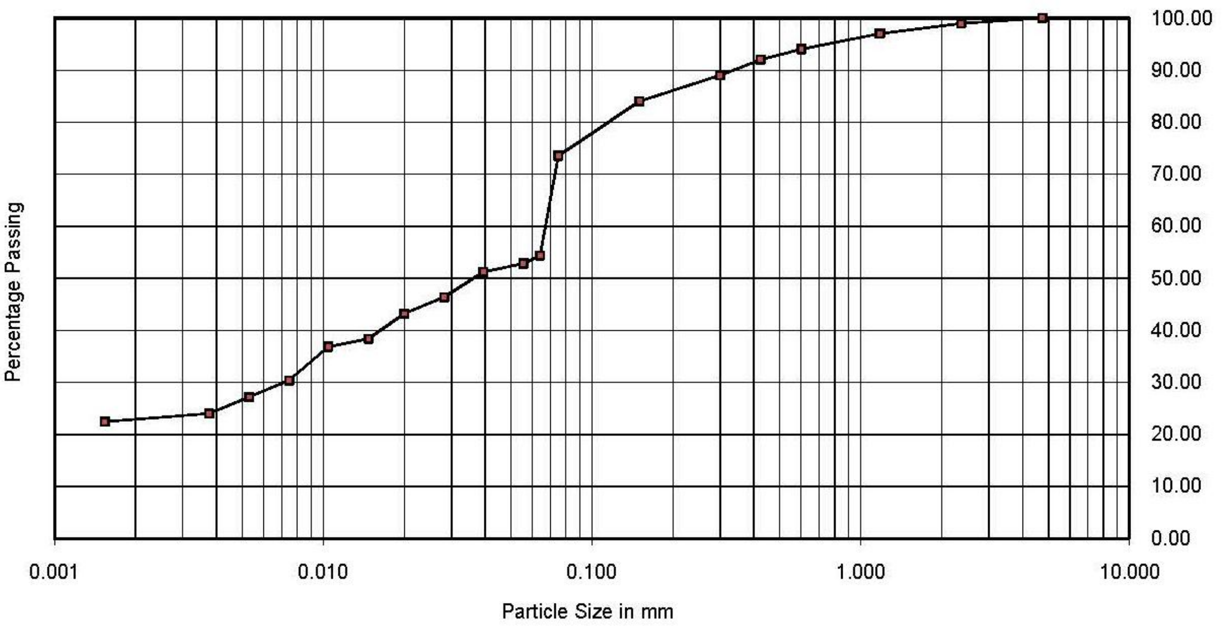
Site:	Anjunem Dam
Sample No.	6



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
6	17.60	60.40	21	1.00

GRAIN SIZE DISTRIBUTION CURVES

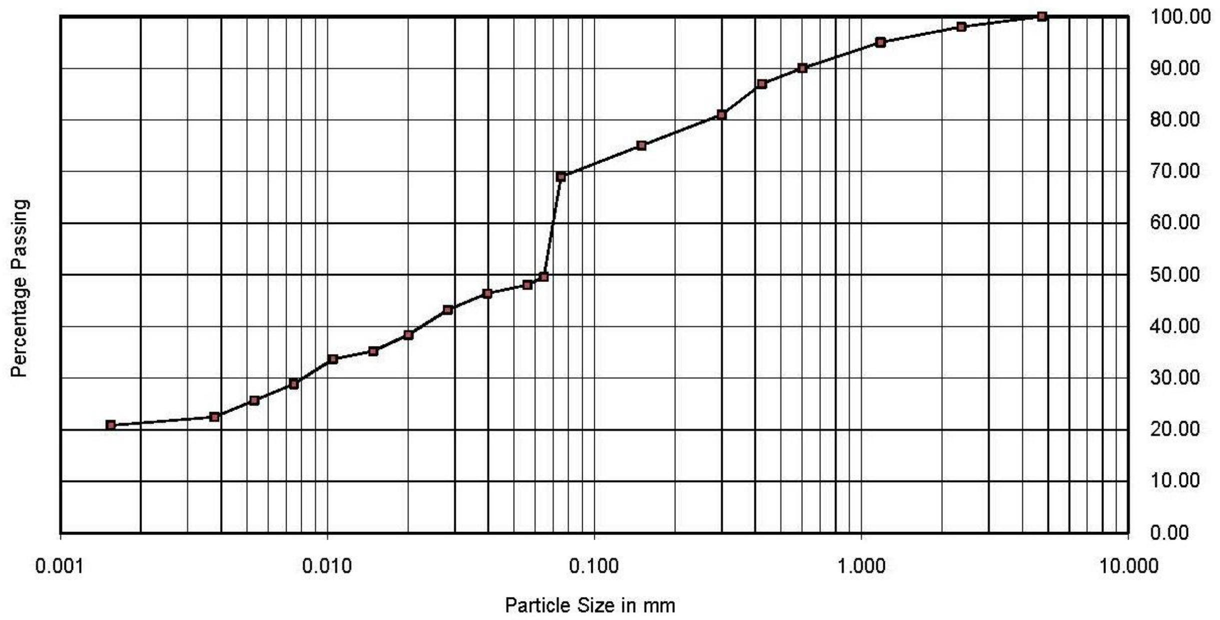
Site:	Anjunem Dam
Sample No.	7



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
7	22.40	51.10	26.50	0.00

GRAIN SIZE DISTRIBUTION CURVES

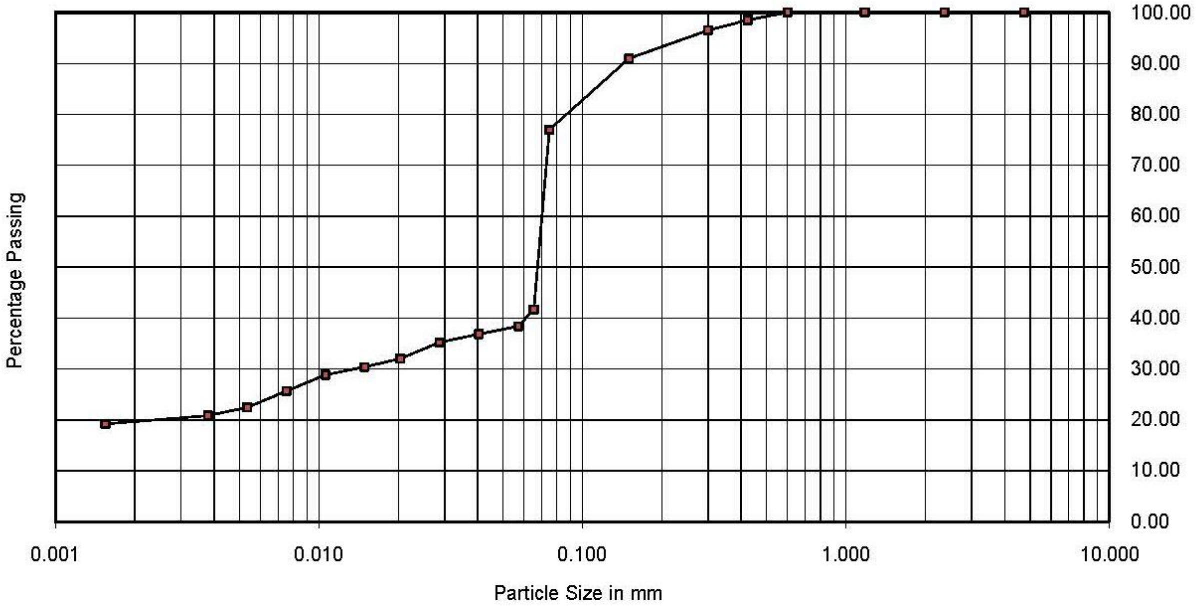
Site:	Anjunem Dam
Sample No.	8



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
8	20.80	48.20	31.00	0.00

GRAIN SIZE DISTRIBUTION CURVES

Site:	Anjunem Dam
Sample No.	9

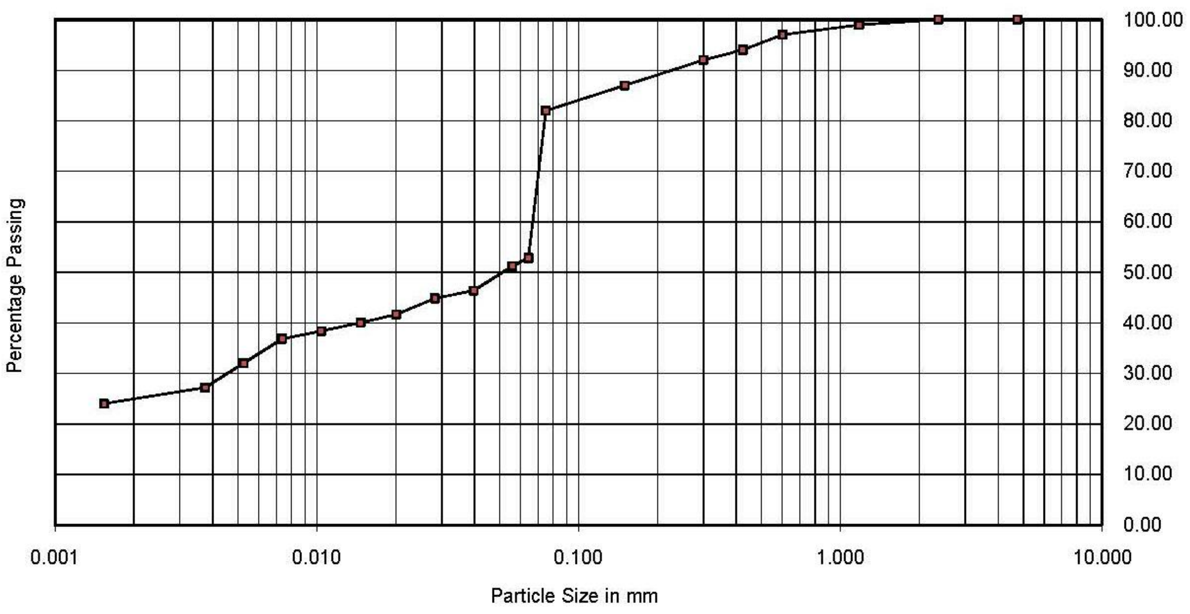


Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
9	19.20	57.80	23	0.00

GRAIN SIZE DISTRIBUTION CURVES

Site: Anjunem Dam

Sample No. 10



Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
10	24.00	58.00	18	0.00

13.3.6 Water Sample report:-

SITE: ANJUNEM DAM							
TEST RESULTS							
Sl. No.	Sample No.	Latitude (N)	Longitude (E)	Depth (m)	pH Value	Sulphate (ppm)	Chloride (ppm)
1	1	15˚37'2.58"	74°5'23.73"	29.87	6.55	70.00	10.00
2	2	15˚37'24.05"	74°5'23.93"	7.90	6.59	60.00	10.00
3	3	15˚37'36.67"	74°5'19.91"	10.3	6.35	50.00	10.00
4	4	15˚37'22.59"	74°5'37.90"	20.42	6.45	60.00	10.00
5	5	15˚37'23.81"	74°5'58.11"	10.6	6.52	60.00	10.00
6	6	15˚37'20.39"	74°6'27.23"	1.23	6.27	70.00	10.00
7	7	15˚37'9.22"	74°5'51.66"	20.7	6.30	50.00	10.00
8	8	15˚36'57.99"	74°5'42.71"	8.93	6.29	80.00	10.00
9	9	15˚37'0.59"	74°5'53.81"	14.58	6.33	70.00	10.00
10	10	15˚36'49.95"	74°6'8.07"	5.5	6.16	80.00	10.00

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CROSS SECTIONS (v)

This section has been analyzed the original bed profile, cross section data and cross sectional drawings etc.

14.0 Cross Sectional Plan of Anjunem Dam near Chainage 0.00 m to Chainage 2300m:-

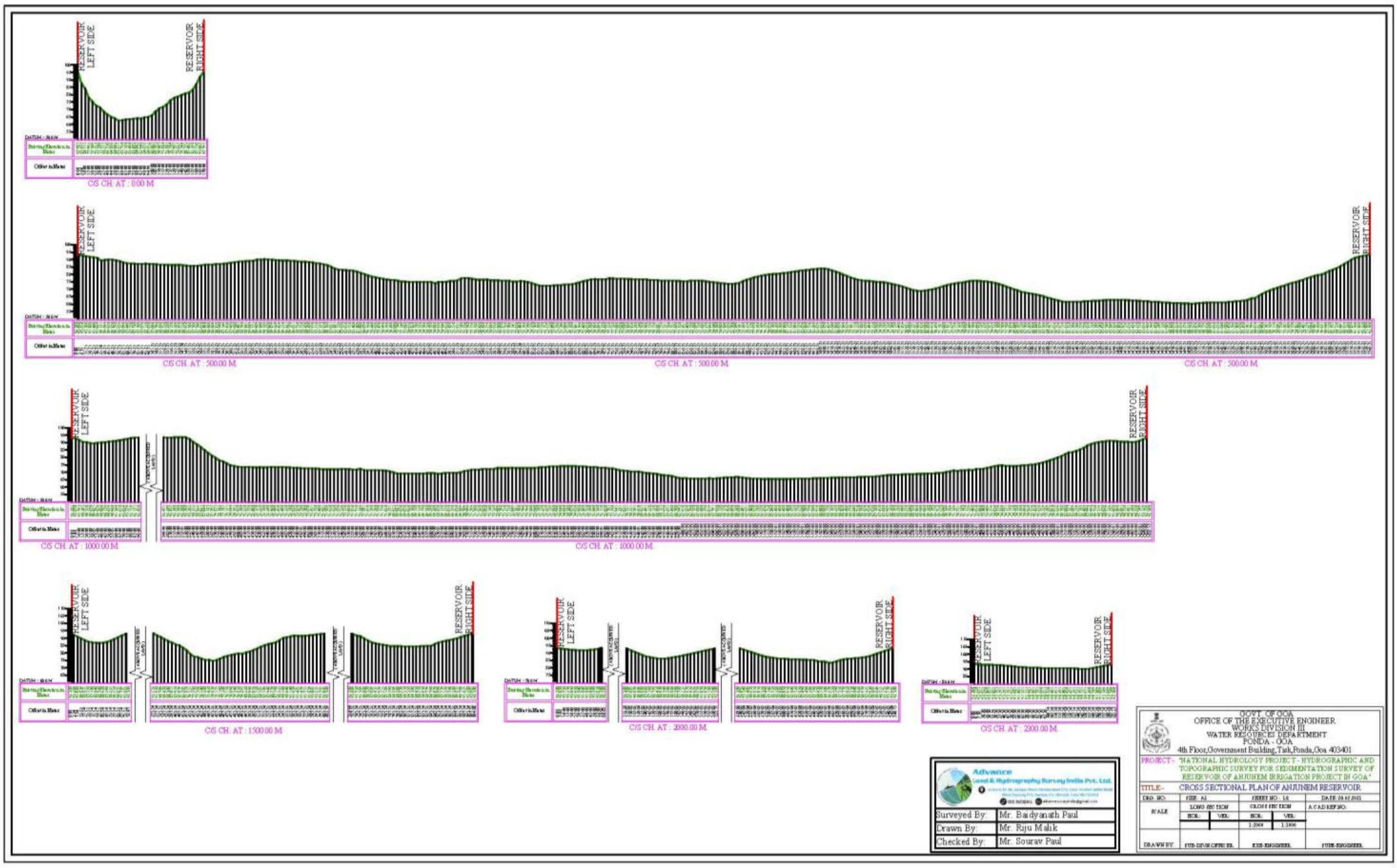

Figure 27-Cross Sectional Plan of Anjunem Dam near Chainage 0.00 m to Chainage 2300m

L- SECTION (vi)

This section has been analyzed longitudinal section drawings

15.0 Long Sectional Plan of Anjunem Dam:-

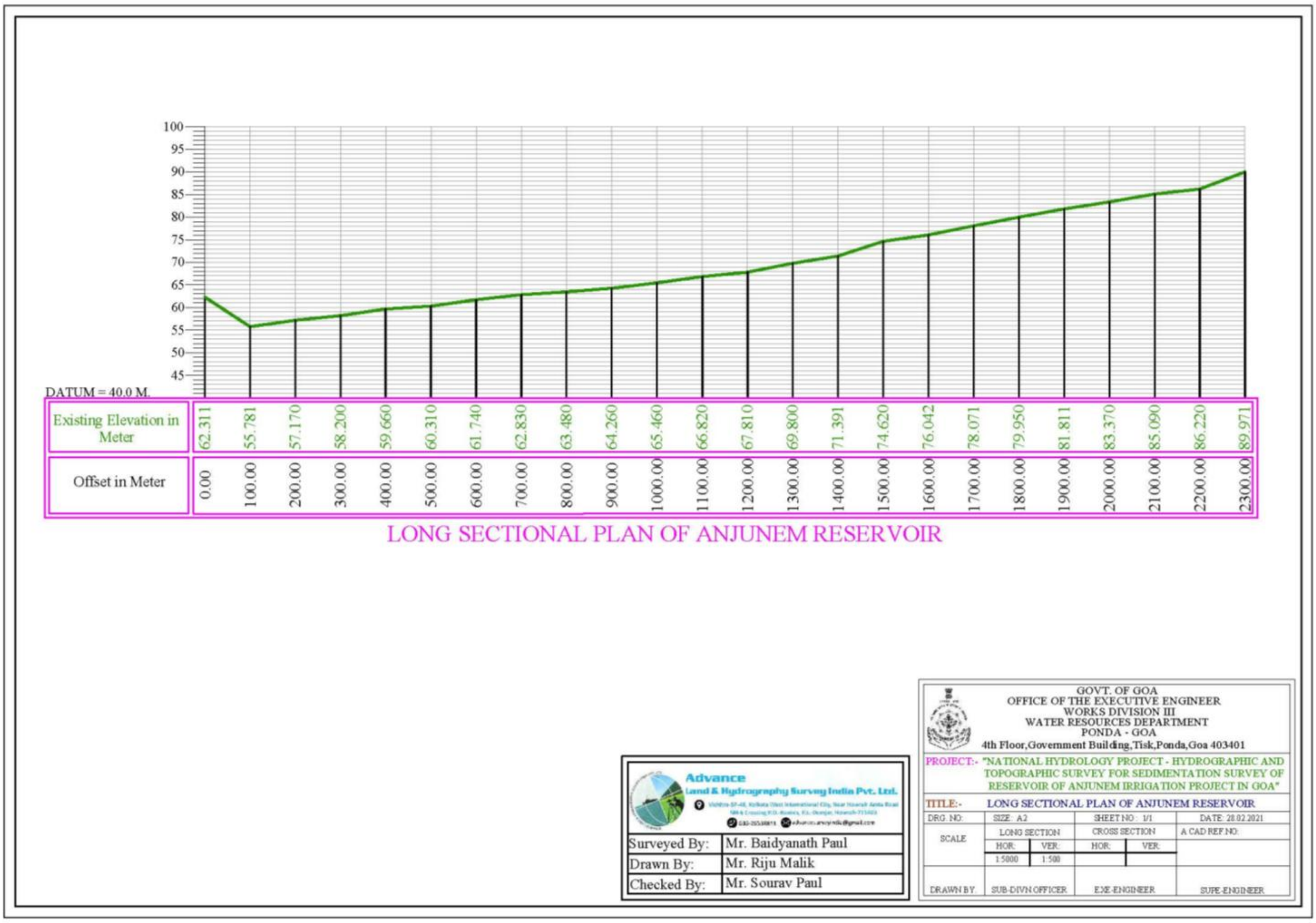

Figure 28-Long section of Anjunem Dam

VERTICAL SEDIMENT DISTRIBUTION (vii)

This section has been analyzed the Vertical Sediment distribution Curve/table, Percent Dam depth and percent sediment deposited in the Anjunem Dam as per I.S. 5477 Part-II 1994.

Table-VIII

- **Capacity of Anjunem Dam in different Zones for different year :-**

The Below table shows the Capacity of Anjunem Dam in different zones for different year i.e. Dead zone, Live zone and Flood zone of the Dam.

Capacity in Anjunem Dam in Different Years In Different zones			
(Capacity In ACRE FEET (MCM), Elevation in ft./m)			
ZONE	Dead Storage	Live Storage	Overall
YEAR	El. 203.41 Ft (62.00 m)	El. 203.41 – 305.77 Ft (62.00 – 93.2 m)	
1984	648.57 (0.8)	35695.70 (44.03)	36344.27 (44.83)
2021	137.82 (0.17)	28634.39 (35.32)	28772.21 (35.49)

Table-VIII A

- **Progressive Loss in Capacity in Anjunem Dam in Different Years in Different Zones :-**

(Capacity in ACRE FEET (MCM), Elevation in ft./meter			
ZONE	Dead storage	Live Storage	Overall
YEAR	El. 203.41 ft (62.0 m)	El.203.41-305.77 ft (62.0 – 93.2 m)	
1984	-	-	-
2021	510.75 (0.63)	7061.31 (8.71)	7572.06 (9.34)

Table-VIII B

- **Progressive Loss Percent in Capacity in Anjunem Dam in Different Years in Different Zones :-**

Elevation in Feet/meter			
ZONE	Dead storage	Live Storage	Overall
YEAR	El. 203.41 ft (62.0 m)	El.203.41-305.77 ft (62.0 – 93.2 m)	
1984	-	-	-
2021	78.75	19.78	20.83

Table-VIII C

- **Progressive Annual Loss Percent in Capacity in Anjunem Dam in Different Years in Different Zones :-**

Elevation in Feet/meter			
ZONE	Dead storage	Live Storage	Overall
YEAR	El. 203.41 ft (62.0 m)	El. 203.41-305.77 ft (62.0 – 93.2 m)	
1984	-	-	-
2021	2.13	0.53	0.56

Table-IX

Average Annual volume of Deposit

VOLUME IN ACRE FEET (MCM)		
	1984	2021
1984	-	205 (0.25)

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CONTOUR MAP (viii)

This section has been indicated contour map of Anjunem Dam

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16.0 Contour Elevation & Area of Anjunem Dam (Sq.m, Hectare and Sq. km):-

SL. NO.	Contour EL (m)	Area		
		in Sqm.	*in Hectare*	*in Sq km.*
1	56.0	602.77	0.060	0.001
2	56.3	1400.56	0.140	0.001
3	56.6	2015.54	0.202	0.002
4	56.9	2637.96	0.264	0.003
5	57.0	2902.28	0.290	0.003
6	57.2	3679.96	0.368	0.004
7	57.5	5129.75	0.513	0.005
8	57.8	6738.72	0.674	0.007
9	58.0	8112.39	0.811	0.008
10	58.1	9014.74	0.901	0.009
11	58.4	11825.23	1.183	0.012
12	58.7	15150.20	1.515	0.015
13	59.0	18700.14	1.870	0.019
14	59.3	23398.55	2.340	0.023
15	59.6	26998.18	2.700	0.027
16	59.9	34754.70	3.475	0.035
17	60.0	38721.99	3.872	0.039
18	60.2	44708.27	4.471	0.045
19	60.5	52819.01	5.282	0.053
20	60.8	59338.41	5.934	0.059
21	61.0	63507.56	6.351	0.064
22	61.1	66000.99	6.600	0.066
23	61.4	73368.09	7.337	0.073
24	61.7	80575.76	8.058	0.081
25	**62.0**	**87424.95**	**8.742**	**0.087**
26	62.3	93870.89	9.387	0.094
27	62.6	101155.15	10.116	0.101
28	62.9	110557.38	11.056	0.111
29	63.0	114054.27	11.405	0.114
30	63.2	122061.46	12.206	0.122
31	63.5	136101.25	13.610	0.136
32	63.8	149988.56	14.999	0.150
33	64.0	160901.50	16.090	0.161
34	64.1	166248.26	16.625	0.166
35	64.4	184091.80	18.409	0.184
36	64.7	200760.64	20.076	0.201
37	65.0	214598.20	21.460	0.215
38	65.3	228236.94	22.824	0.228
39	65.6	242314.87	24.231	0.242

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SL. NO.	Contour EL (m)	Area		
		in Sqm.	in Hectare	in Sq km.
40	65.9	256552.06	25.655	0.257
41	66.0	261464.72	26.146	0.261
42	66.2	272185.32	27.219	0.272
43	66.5	287563.76	28.756	0.288
44	66.8	303173.87	30.317	0.303
45	67.0	315124.69	31.512	0.315
46	67.1	321853.68	32.185	0.322
47	67.4	341073.14	34.107	0.341
48	67.7	362205.80	36.221	0.362
49	68.0	383972.18	38.397	0.384
50	68.3	404932.63	40.493	0.405
51	68.6	425510.02	42.551	0.426
52	68.9	446803.27	44.680	0.447
53	69.0	454059.80	45.406	0.454
54	69.2	469344.29	46.934	0.469
55	69.5	494909.75	49.491	0.495
56	69.8	519757.24	51.976	0.520
57	70.0	536609.85	53.661	0.537
58	70.1	545144.38	54.514	0.545
59	70.4	569915.08	56.992	0.570
60	70.7	593994.73	59.399	0.594
61	71.0	616201.02	61.620	0.616
62	71.3	640711.35	64.071	0.641
63	71.6	665811.20	66.581	0.666
64	71.9	692160.43	69.216	0.692
65	72.0	701202.76	70.120	0.701
66	72.2	718710.94	71.871	0.719
67	72.5	745062.28	74.506	0.745
68	72.8	771398.67	77.140	0.771
69	73.0	789639.35	78.964	0.790
70	73.1	798487.33	79.849	0.798
71	73.4	825717.67	82.572	0.826
72	73.7	852551.86	85.255	0.853
73	74.0	878856.57	87.886	0.879
74	74.3	904964.24	90.496	0.905
75	74.6	929977.17	92.998	0.930
76	74.9	955909.43	95.591	0.956
77	75.0	965505.13	96.551	0.966
78	75.2	984705.87	98.471	0.985
79	75.5	1012489.20	101.249	1.012
80	75.8	1036488.93	103.649	1.036
81	76.0	1052478.29	105.248	1.052
82	76.1	1060458.76	106.046	1.060
83	76.4	1084136.07	108.414	1.084

SL. NO.	Contour EL (m)	Area		
		in Sqm.	in Hectare	in Sq km.
84	76.7	1105783.86	110.578	1.106
85	77.0	1126374.82	112.637	1.126
86	77.3	1146390.94	114.639	1.146
87	77.6	1167315.61	116.732	1.167
88	77.9	1187716.45	118.772	1.188
89	78.0	1194430.83	119.443	1.194
90	78.2	1207566.40	120.757	1.208
91	78.5	1226963.89	122.696	1.227
92	78.8	1246434.06	124.643	1.246
93	79.0	1259768.11	125.977	1.260
94	79.1	1266369.50	126.637	1.266
95	79.4	1285655.03	128.566	1.286
96	79.7	1304373.65	130.437	1.304
97	80.0	1322225.83	132.223	1.322
98	80.3	1340224.18	134.022	1.340
99	80.6	1357356.17	135.736	1.357
100	80.9	1375223.61	137.522	1.375
101	81.0	1380984.53	138.098	1.381
102	81.2	1392623.94	139.262	1.393
103	81.5	1411522.78	141.152	1.412
104	81.8	1431373.48	143.137	1.431
105	82.0	1445406.45	144.541	1.445
106	82.1	1452345.60	145.235	1.452
107	82.4	1473711.70	147.371	1.474
108	82.7	1495077.17	149.508	1.495
109	83.0	1515142.49	151.514	1.515
110	83.3	1536041.48	153.604	1.536
111	83.6	1557041.68	155.704	1.557
112	83.9	1577506.31	157.751	1.578
113	84.0	1584381.35	158.438	1.584
114	84.2	1598371.74	159.837	1.598
115	84.5	1620182.10	162.018	1.620
116	84.8	1643076.12	164.308	1.643
117	85.0	1658770.07	165.877	1.659
118	85.1	1667024.38	166.702	1.667
119	85.4	1691746.04	169.175	1.692
120	85.7	1717149.55	171.715	1.717
121	86.0	1742701.00	174.270	1.743
122	86.3	1768626.88	176.863	1.769
123	86.6	1795006.45	179.501	1.795
124	86.9	1821322.68	182.132	1.821
125	87.0	1830385.89	183.039	1.830
126	87.2	1849062.79	184.906	1.849
127	87.5	1877213.92	187.721	1.877

SL. NO.	Contour EL (m)	Area		
		in Sqm.	in Hectare	in Sq km.
128	87.8	1898312.54	189.831	1.898
129	88.0	1910983.39	191.098	1.911
130	88.1	1917135.61	191.714	1.917
131	88.4	1935312.07	193.531	1.935
132	88.7	1953315.78	195.332	1.953
133	89.0	1971631.71	197.163	1.972
134	89.3	1989939.47	198.994	1.990
135	89.6	2008261.12	200.826	2.008
136	89.9	2027059.17	202.706	2.027
137	90.0	2033439.98	203.344	2.033
138	90.2	2046408.19	204.641	2.046
139	90.5	2066405.70	206.641	2.066
140	90.8	2086949.54	208.695	2.087
141	91.0	2100964.84	210.096	2.101
142	91.1	2108018.73	210.802	2.108
143	91.4	2129746.92	212.975	2.130
144	91.7	2152216.90	215.222	2.152
145	92.0	2175256.56	217.526	2.175
146	92.3	2198710.84	219.871	2.199
147	92.6	2222154.36	222.215	2.222
148	92.9	2244871.91	224.487	2.245
149	93.0	2251992.82	225.199	2.252
150	**93.2**	**2264811.31**	**226.481**	**2.265**

Table 14-Contour Elevation Data (in Sq.km, Sq. m. and Hectare)

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Contour Plan of Anjunem Dam

17. Contour Plan of Anjunem Dam:-

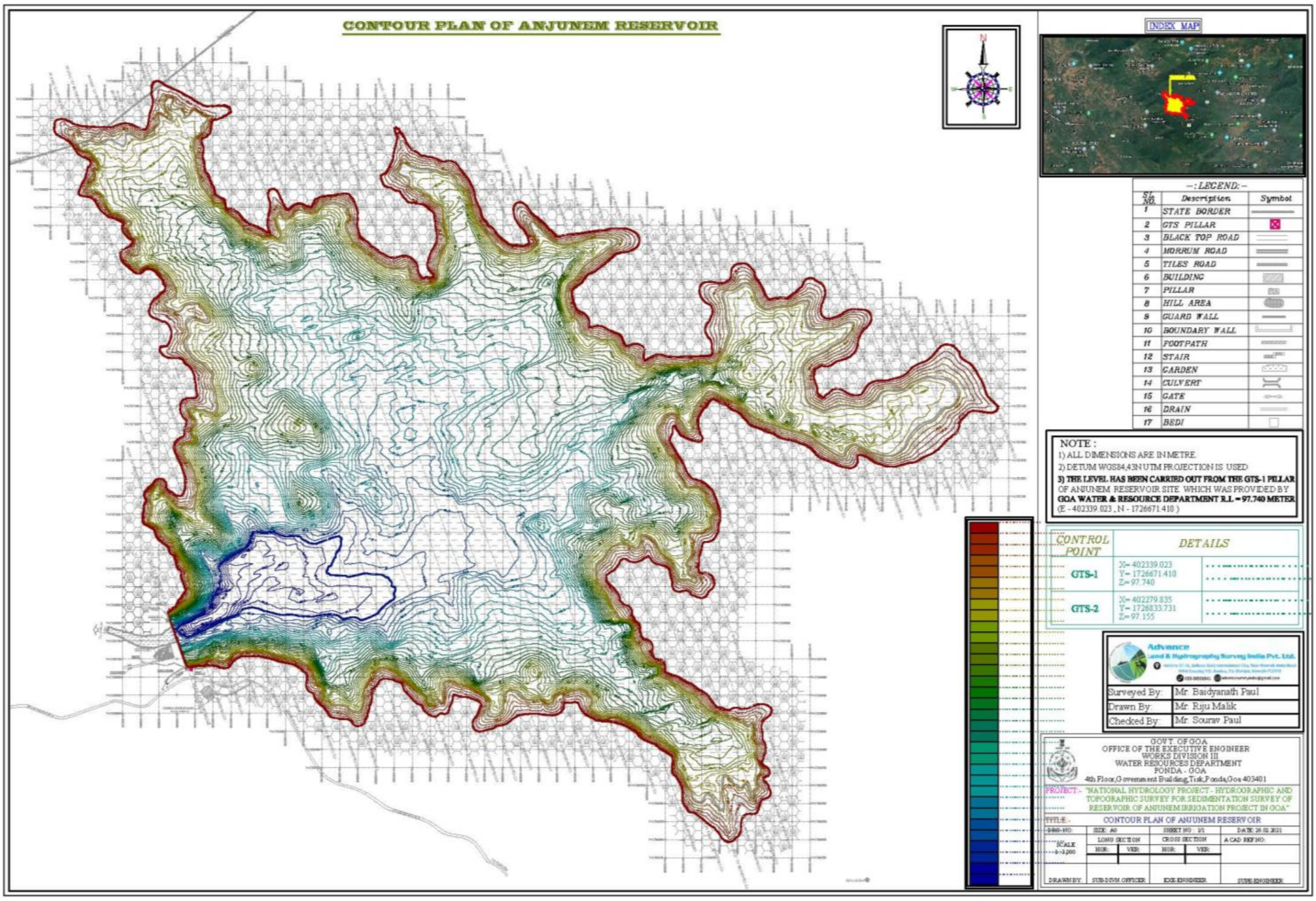

Figure 29-Contour Plan of Anjunem Dam

TRAP EFFICIENCY (ix)

This section has been analyzed the trap efficiency of Anjunem Dam according to Brune'S curve as per I.S. 12182-1987

18.0 Trap Efficiency of Dam (IS 12182-1987):-

The Trap efficiency of Anjunem Dam has been calculated according to Brune'S trap efficiency curve as per I.S 12182-1987 "Guidelines for determination of effects of sedimentation of Effects of sedimentation in planning and performance of Dams".

Trap efficiency can be defined as the ratio between the total sediment deposited in a Dam and the total sediment flowing in the river for a certain period.

Therefore, trap Efficiency:-

$$\frac{\text{Total Sediment deposited in the Dam}}{\text{Total Sediment Flowing in the River}}$$

Trap efficiency of a Dam, over a period is the ratio of the total deposited sediment inflow. Gunnar Brune analyzed data from the Dams with catchment areas varying from small to very large and presented a median curve together with lower and upper envelope curves which is shown below –

Trap efficiency of a reservoir, over a period is the ratio of the total deposited sediment to the total sediment inflow. Brune (1953) developed an empirical relationship for estimating long-term trap efficiency in normally impounded reservoirs based on the correlation between the capacity to inflow ratio (C: I) and trap efficiency observed in Tennessee Valley Authority reservoirs in the south-eastern United States. Brune analysed data from 44 reservoirs with catchment areas varying from small to very large and presented a median curve together with lower and upper envelope curves which shows in Fig-30.

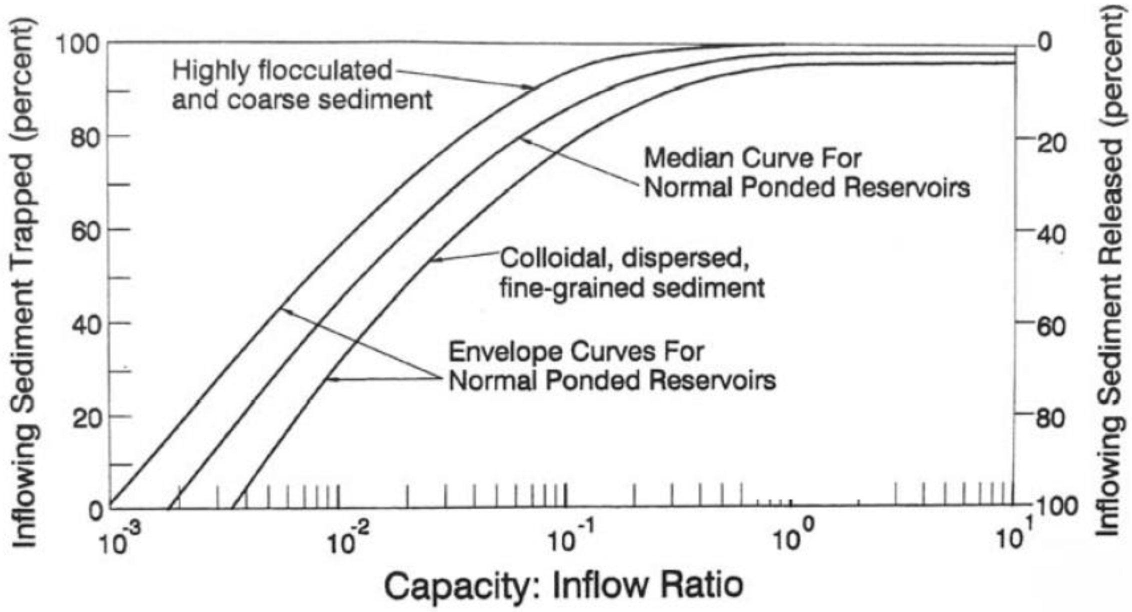

Figure 30-Brune curve for estimating sediment trapping or release efficiency in conventional impounding reservoirs (adapted from Brune. 1953)

This is probably the most widely used method for estimating the sediment retention in reservoirs and gives reasonable results from very limited data: storage volume and average annual inflow. As a limitation, the method is applicable only to long-term average conditions. Brune noted that significant departures can occur because of changes in the operating rule. Trapping efficiency also depends on the actual storage level at which the reservoir is held during flood periods (as opposed to its nominal storage capacity), and the placement of outlets.

Capacity = Capacity of Reservoir at FRL

Inflow = Average annual inflow in volumetric unit

For Anjunem Dam C = 35.49 MCM based on 2021 survey

I = 133.32 MCM

C/I = 0.266

Trap efficiency corresponding to above ratio C/I as read from median curve of Fig-30 for normally ponded reservoir is 94%.

CHARTS/DRAWINGS (x)

19.0 Charts/Drawing:-

19.1 Grid Plan of Anjunem Dam:-

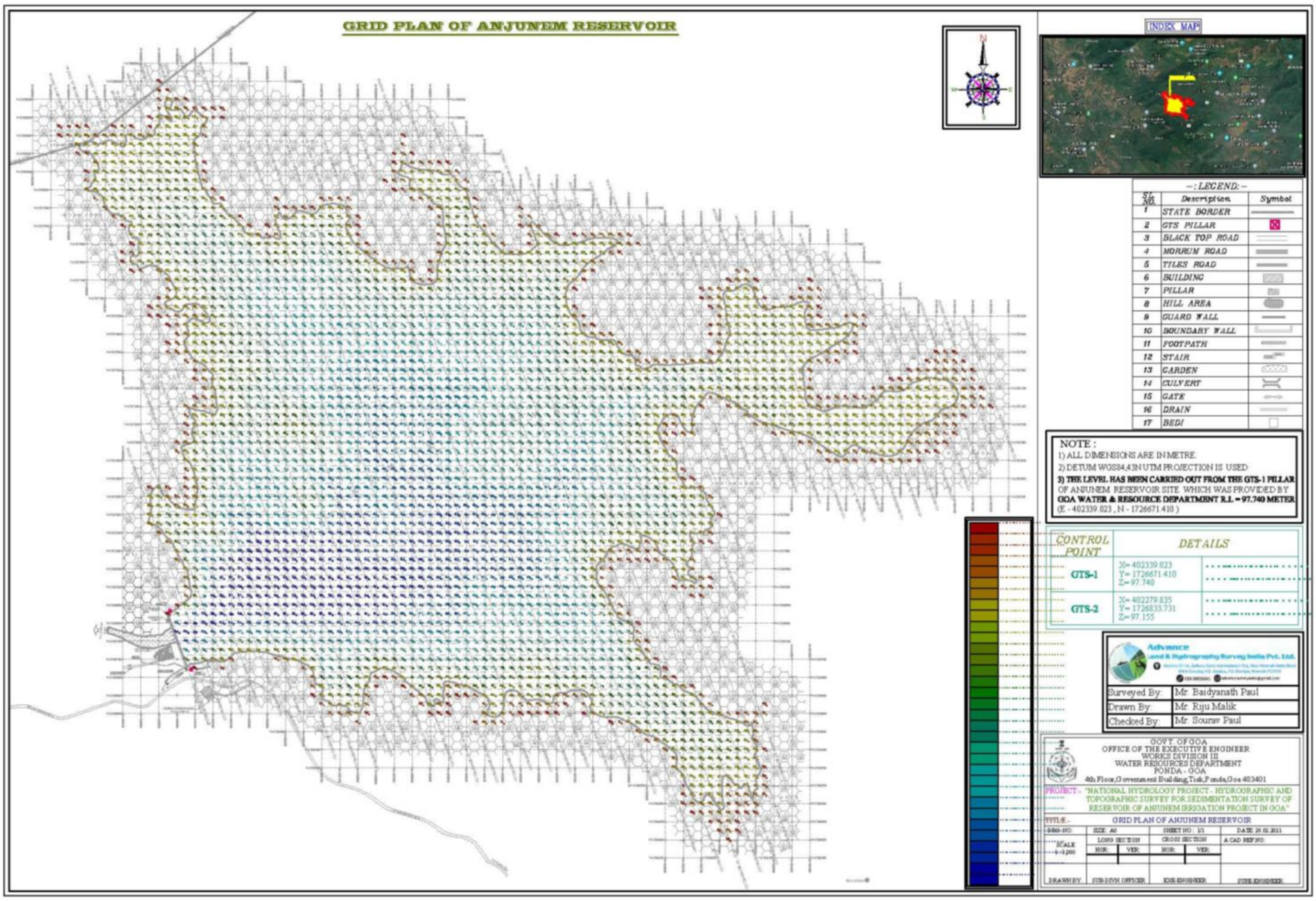

Figure 31-Grid plan of Anjunem Dam

19.2 Topographical Plan of Anjunem Dam:-

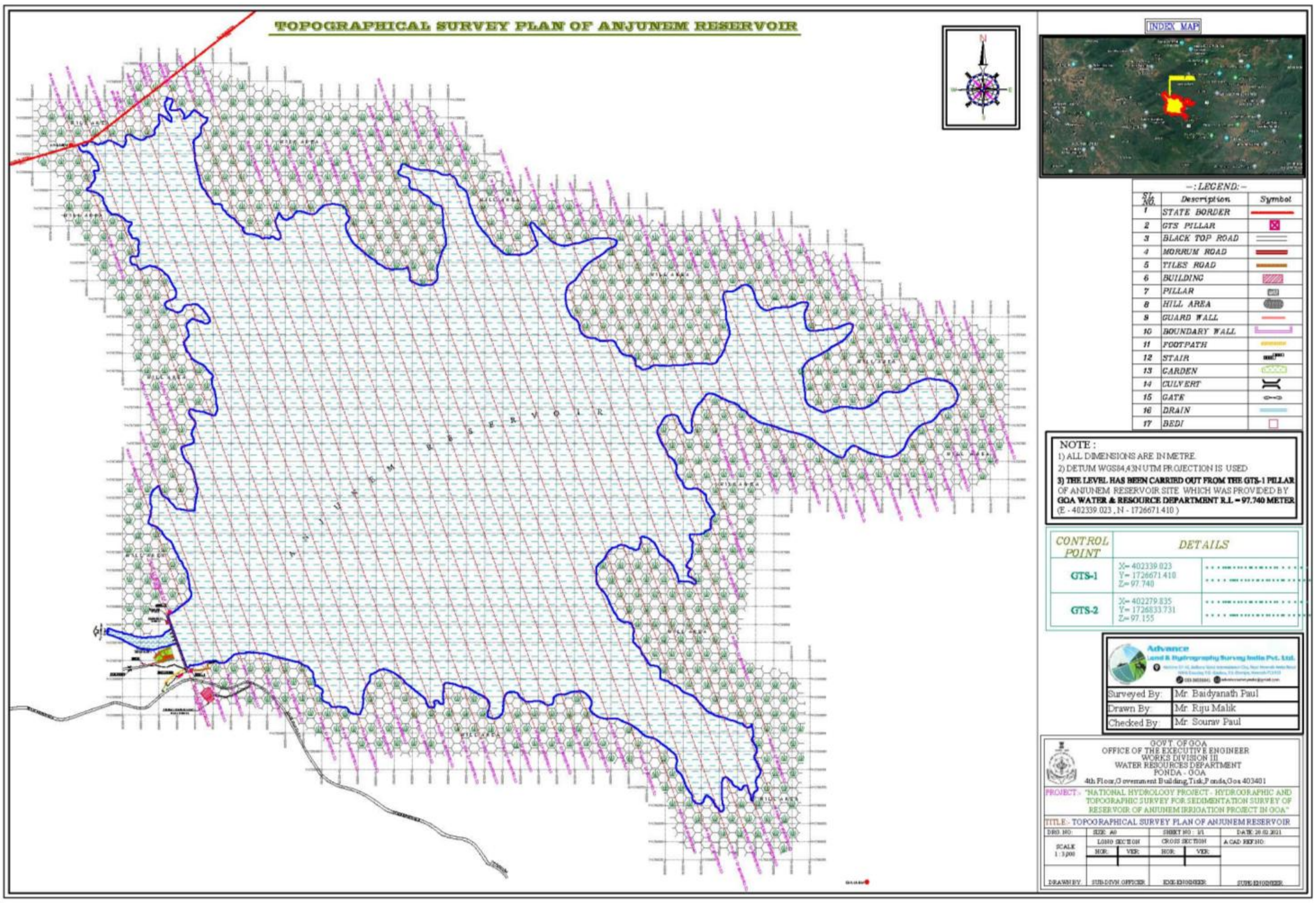

Figure 32-Topographical Survey plan of Anjunem Dam

CONCLUSIONS/RECOMMENDATIONS

20.0 Conclusion & Recommendation:-

- It is observed that dead storage will be depleted within 10 years from 2021.
- 50% of live storage will be depleted within 50 years from 2021.
- It is recommended to find the source of sediment from the catchment and a detailed study need to be done for catchment area treatment plan.
- Suspended sediment data need to be collected each year for monsoon period to understand the sediment inflow coming each year during monsoon.
- Sediment management can be done either by flushing or sluicing. Flushing can be done if enough water is available. Otherwise sluicing with maintaining low water level during peak flood can be option. A detailed mathematical model study is recommended to analyse and find an optimized solution for sediment management.
- Dredging could be another option for sediment management.

Control of sediment deposition:-

The deposition of sediment in a Dam may be controlled to a certain extent by designing and operating gates or other outlets in the dam in such a manner as to permit selective withdrawals of water having a higher than average sediment content. The suspended sediment content of the water in Dams is higher during and just after flood flow. Thus, more the water wasted at such times, the smaller will be the percentage of the total sediment load to settle into permanent deposits. There are generally two methods: (a) density currents, and (b) waste-water release, for controlling the deposition and both will necessarily result in loss of water.

1. Density Current :-

Water at various levels of a Dam often contains radically different concentrations of suspended sediment particularly during and after flood flows and if all waste-water could be withdrawn at those levels where the concentration is highest, a significant amount of sediment might be removed from the Dam. Because a submerged outlet draws water towards it from all directions, the vertical dimension of the opening should be small with respect to the thickness of the layer and the rate of withdrawal also should be low. With a view to passing the density current by sluices that might be existed, it is necessary to trace the movement of density currents and observation stations (consisting of permanently anchored rafts from which measurements could be made of temperature and conductivity gradient from the surface of the lake to the bottom, besides collecting water samples at various depths) at least one just above the dam and two or more additional stations in the upstream (one in the inlet and one in the middle) should be located.

2. Waste-Water Release :-

Controlling the sedimentation by controlling waste-water release is obviously possible only when water can be or should be wasted. This method is applicable only when a Dam is of such size that a small part of large flood flows will fill it.

In the design of the dam, sediment may be passed through or over it as an effective method of silt control by placing a series of outlets at various elevations. The percentage of total sediment load that might be ejected from the Dam through proper gate control will differ greatly with different locations. It is probable that as much as 20 percent of the sediment inflow could be passed through many Dams by venting through outlets designed and con- trolled.

3. Scouring Sluicing :-

This method is somewhat similar to both the control of waste-water release and the draining and flushing methods. The distinction amongst them cares the following:

1) The waste-water release method ejects sediment laden flood flows through deep spillway gates or large under sluices at the rate of discharge that prevents sedimentation.

2) Drainage and flushing method involves the slow release of stored water from the Dam through small gates or valves making use of normal or low flow to entrain and carry the sediment and

3) Scouring sluicing depends for its efficiency on either the scouring action exerted by the sudden rush of impounded water under a high head through under sluices or on the scouring action of high flood discharge coming into the Dam.

Scouring sluicing method can be used in the following:

a) Small power dams that depend to a great extent on pondage but not on storage;

b) Small irrigation Dams, where only a small fraction of the total annual flow can be stored;

c) Any Dam in narrow channels, gorges, etc, where water wastage can be afforded; and

d) When the particular Dam under treatment is a unit in an interconnected system so that the other Dams can supply the water needed.

4. Draining and Flushing :-

The method involves relatively slow release of all stored water in a Dam through gates or valves located near bottom of the dam and the maintenance thereafter of open outlets for a shorter or longer period during which normal stream flow cuts into or directed against the sediment deposits. Therefore, this method may be adopted in flood control Dams.

5. Sluicing with Controlled Water :-

This method differs from the flood sluicing in that the controlled water supply permits choosing the time of sluicing more advantageously and that the water may be directed more effectively against the sediment deposits. While the flood sluicing depends either on the occurrence of flood or on being able to release rapidly all of a full or nearly full supply of water in the main Dam is empty. The advantage of this method is that generally more sediment can be removed per unit of water used than in flood scouring or draining and flushing.

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6. Sluicing with Hydraulics and Mechanical Agitation :-

Methods that stir up break up or move deposits of sediment into a stream current moving through a drained Dam basin or into a full Dam will tend to make the removal of sediment from the Dam more complete. Wherever draining, flushing or sluicing appear to be warranted, the additional use of hydraulic means for stirring up the sediment deposits, or sloughing them off, into a stream flowing through the Dam basin should be considered. It has, however, limited application.

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Appendix A: Sample calculation for 30 yr

Determination of Sediment Inflow

Capacity at FRL 93.2 m in 1984 = 44.83 MCM

Capacity at FRL 93.2 m in 2021 = 35.494 MCM

Sediment accumulated in 37 yr = 9.336 MCM

Sediment accumulated per yr = 0.252 MCM

Trap Efficiency

Gross capacity of reservoir at FRL = 35.494 MCM

Inflow = 133.32 MCM

Capacity Inflow Ratio (C/I) = 0.266

From Brune's curve trap efficiency = 94.00%

Classification of reservoir

Bed Level =54 m

FRL = 93.2 m

Total depth of water = 39.2

For 1984

Plot depth vs capacity on log-log plot

Inverse of slope of the graph (m)

From dead storage level slope is predominantm = 2.64

Shape of reservoir (from table) =Floodplain-foothill

Determination of new zero elevation after 50 years

Total Sediment deposition (S) =7.57 MCM

Dimensionless function (F) = $(S-V_h)/(HA_h)$

Relative Depth (p) = $(h-h_{min})/H$

Relative depth at new zero elevation is p_0 = 0.281

p_0 is calculated from F vs Relative depth curve sheet

New zero elevation = 65.01 m (say 65 m)

Corresponding Area (A0) = 24.85 ha

Distribute Sediment

Type II: $a = 2.487p^{0.57}(1-p)^{0.41}$

Relative Sediment area (a) for Type II for p_0 = 0.281 = 1.053652

Area correction factor = A0/a = 23.585 ha

Relative						Computed Sediment Distribution			Revised	
Elevation h,m	Area A, ha	Capacity V_h, 10^6 m^3	F	Depth p	Area a	Area ,ha	Volume Increment, 10^6 m^3	Cumulative Volume, 10^6 m^3	Area ha	Capacity 10^6 m^3
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
93.2	229.78	35.49		1.000	0	0.000	0.08279	7.57	229.778	27.924
92	214.52	32.83		0.969	0.585055	13.798	0.15611	7.49	200.724	25.341
91	212.98	30.69		0.944	0.738795	17.424	0.18713	7.33	195.559	23.360
90	200.36	28.62		0.918	0.848124	20.003	0.21004	7.14	180.354	21.480
89	200.10	26.62		0.893	0.933053	22.006	0.22816	6.93	178.095	19.688
88	188.16	24.68		0.867	1.001751	23.626	0.24295	6.71	164.535	17.975
87	186.67	22.81		0.842	1.058495	24.964	0.25523	6.46	161.704	16.344
86	170.59	21.02		0.816	1.105853	26.081	0.26549	6.21	144.507	14.813
85	169.50	19.32		0.791	1.145501	27.016	0.27407	5.94	142.479	13.378
84	154.65	17.70		0.765	1.178603	27.797	0.28120	5.67	126.854	12.031
83	155.33	16.15		0.740	1.206003	28.443	0.28706	5.39	126.889	10.762
82	140.80	14.67		0.714	1.22833	28.970	0.29179	5.10	111.827	9.569
81	141.62	13.26		0.689	1.246064	29.388	0.29547	4.81	112.234	8.448
80	128.72	11.90		0.663	1.259579	29.707	0.29820	4.51	99.012	7.392
79	129.60	10.61		0.638	1.269169	29.933	0.30002	4.21	99.670	6.399

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Relative						Computed Sediment Distribution			Revised	
Elevation h,m	Area A, ha	Capacity V_h, 10^6 m^3	F	Depth p	Area a	Area ,ha	Volume Increment, 10^6 m^3	Cumulative Volume, 10^6 m^3	Area ha	Capacity 10^6 m^3
78	115.80	9.39		0.612	1.275063	30.072	0.30100	3.91	85.727	5.472
77	116.27	8.23		0.587	1.277443	30.128	0.30116	3.61	86.139	4.612
76	101.86	7.13	0.011	0.561	1.276448	30.105	0.30054	3.31	71.758	3.823
75	100.31	6.12	0.037	0.536	1.272183	30.004	0.29916	3.01	70.303	3.113
74	84.05	5.20	0.072	0.510	1.264725	29.828	0.29703	2.71	54.219	2.490
73	82.85	4.37	0.099	0.485	1.25412	29.578	0.29416	2.42	53.273	1.953
72	66.18	3.62	0.152	0.459	1.240391	29.254	0.29055	2.12	36.921	1.502
71	65.40	2.96	0.180	0.434	1.223534	28.857	0.28621	1.83	36.544	1.134
70	50.09	2.39	0.264	0.408	1.203522	28.385	0.28111	1.54	21.707	0.843
69	48.87	1.89	0.296	0.383	1.180298	27.837	0.27524	1.26	21.034	0.629
68	34.89	1.47	0.446	0.357	1.153779	27.211	0.26858	0.99	7.676	0.486
67	34.85	1.12	0.472	0.332	1.123846	26.505	0.26110	0.72	8.348	0.406
66	22.70	0.84	0.757	0.306	1.09034	25.715	0.25276	0.46	0.000	0.379
65	24.85	0.60	0.716	0.281	1.053056	24.836	0.24349	0.21	0.000	0.000
64	12.94	0.41	1.411	0.255	1.011725	23.861	0.23322			
63	14.33	0.27	1.299	0.230	0.965999	22.783	0.22186			
62	4.5	0.18	4.189	0.204	0.915419	21.590	0.22744			
60.91	2.5	0.17	7.546	0.176	0.854035	20.142	0.52862			
57.91	2	0.10	9.528	0.100	0.640226	15.099	0.33076			
54.86	2	0.04	9.604	0.022	0.279394	6.589	0.02833			
54	0	0.00		0.000	0	0.000	0.00000			

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21.0 Personnel:-

The Following Personnel were associated with the Sedimentation Survey of Anjunem Dam:-

- **Survey:-**
  1. Shri Baidyanath Pal, Surveyor
  2. Shri Nayan Manna, Assistant Surveyor
  3. Shri Dipankar Mal, Assistant Surveyor

- **Official Incharge of Anjunem (Dam) Irrigation Project:-**
  1. **Satishchandra C. Sawant, Assistant Engineer**
  2. **Dilip T. Gaonkar, Technical Assistant**

21.1 Guidance/Recommendation and consultation of the Report:-

Name- Arun Kumar Roy
Designation- Chief Consultant Research & Hydro Solutions
[Retired Chief Engineer, Inland waterways Authority of India (I.W.A.I)]

Name-Bimalendu Ghosh

Designation- Senior Survey Consultant

The Institution of Surveyors (Delhi)

Name-Apurban Mukherjee

Designation- Specialisation in Water Resources,

IIT, Guwahati

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21.2 Certificate of Arun Roy:-

भारतीय अन्तर्देशीय जलमार्ग प्राधिकरण
(पोत परिवहन मंत्रालय, भारत सरकार)
मुख्यालय : ए–13, सैक्टर–1, नौएडा–201 301, (उ० प्र०)

INLAND WATERWAYS AUTHORITY OF INDIA
(Ministry of Shipping, Govt. of India)
Head Office : A-13, Sector-1, Noida-201 301 (U.P.)
Website : www.iwai.gov.in | www.iwai.nic.in
Tel. : +91-120-2544036, 2543972, 2527667, 2448101 Fax : +91-120-2544009, 2544041, 2543973, 2521764

No.11/IWAI/Estt./10/2016 Part

Dated:-28.05.2018

OFFICE MEMORANDUM

Consequent upon acceptance of recommendation of 7th CPC and instruction as contained in DoPT OM No. 38/37/2016-P&PW(A) dated 12.05.2017, No.38/37/2016-P&PW(A) dated 06.07.2017 and OM No.IWT-11011/15/2017-IWT dated 19.12.2017, Competent Authority has approved revision of pension/family pension w.e.f 01.01.2016 to the officials superannuated/expired prior to 2016 as per details mentioned under:

Annuity No:	Original PPO No:	Last Corrigendum PPO No:
011M1223142101	-	12/IWAI/Estt./03/2014 Dated: 31.07.2014

BASIC PARTICULARS

Name of Pensioner	Type of Pension	Date of Death of Employee/Pensioner (in case of family pension)
SH. ARUN ROY	SUPERANNUATION	-

Name of Deceased Employee (in case of Family Pension)	Relation of Pensioner with deceased employee (in case of Family Pension)	Post last held with scale of pay
-	-	CHIEF ENGINEER (Rs 37400-67000+GP8700/-)

Office Address	Pensioner's/Family Pensioner's Address
IWAI, Guwahati	Sh. Arun Roy Flat No.4D, Capricorn Castle, 188/93 A, Prince Anwar Shah Road, Kolkata-700045 (WB)

Date of Appointment in Service	Basic Pay and Scale of Pay at the time of Retirement/Death	Date of Retirement
19.08.1987	Rs. 37400-67000 + G.P. 8700/-	30.11.2014

Last Pay Drawn(Pay in Pay Band and Grade Pay to be separately shown in case of 6th CPC)	Notional Pay as on 01.01.2016(in the corresponding Pay Scale under 7th CPC as per Concordance Table-with Table No.)
Rs. 46380+8700 = 55080/-	Rs. 1,42,700/- (as per Table no. 44)

PENSIONARY ENTITLEMENT

Sl.No.	Particular	Pensioner	Spouse/Family (only in Service Pension PPO)
1.	Name	Sh. Arun Roy	Smt. Disha Roy (Wife)
2.	Date of Birth	20.11.1954	09.07.1968
3.	PAN Number	ADLPR1433J	
4.	Aadhaar Number	8090 5548 6311	
5.	Telephone/Mobile Number		
6.	E-mail ID	arunroy1@yahoo.com	
7.	Pre-Revised Basic Pension/Family Pension (As per circular No. C-153) before 01.01.2016	Rs. 27,540/- (Pension) Rs. 16,524/- (Family Pension)	
8.	Revised Rate of Pension / Family Pension wef 01.01.2016 (multiplying pre revised pension by 2.57	Rs. 70,778/- (Pension) Rs. 42,467/- (Family Pension)	
9.	Revised Pension wef 01.01.2016 as per Concordance Table-with Table No. 44	Rs. 71,350/-	
10.	Revised Family Pension wef 01.01.2016 as per Concordance Table-with Table No. 44	Rs. 42,810/-	
11.	Revised Pension payable wef 01.01.2016 (higher of serial no. 8 & 9)	Rs. 71,350/-	
12.	Revised Family Pension (at normal rate) payable wef 01.01.2016 (higher of sl. no. 8&10)	Rs. 42,810/- (wef. 20.11.2021)	
13.	Revised Family Pension at Enhanced Rate	Rs. 71,350/- (upto 19.11.2021)	
14.	Amount of Pension Commuted and Date of Commutation/Date of Payment of Commuted Value	Rs. 11,016/-	
15.	Revised Residual Pension wef 01.01.2016 (sl. no. 11-14)	Rs. 60,334/-	
16.	Medical Allowance	Separate order will be issued	

(Arun Roy), FIE, B.Tech IIT Kharagpur
Chief Consultant, river research & Hydro solutions
(Retired Chief Engineer, Inland waterways Authority of India)

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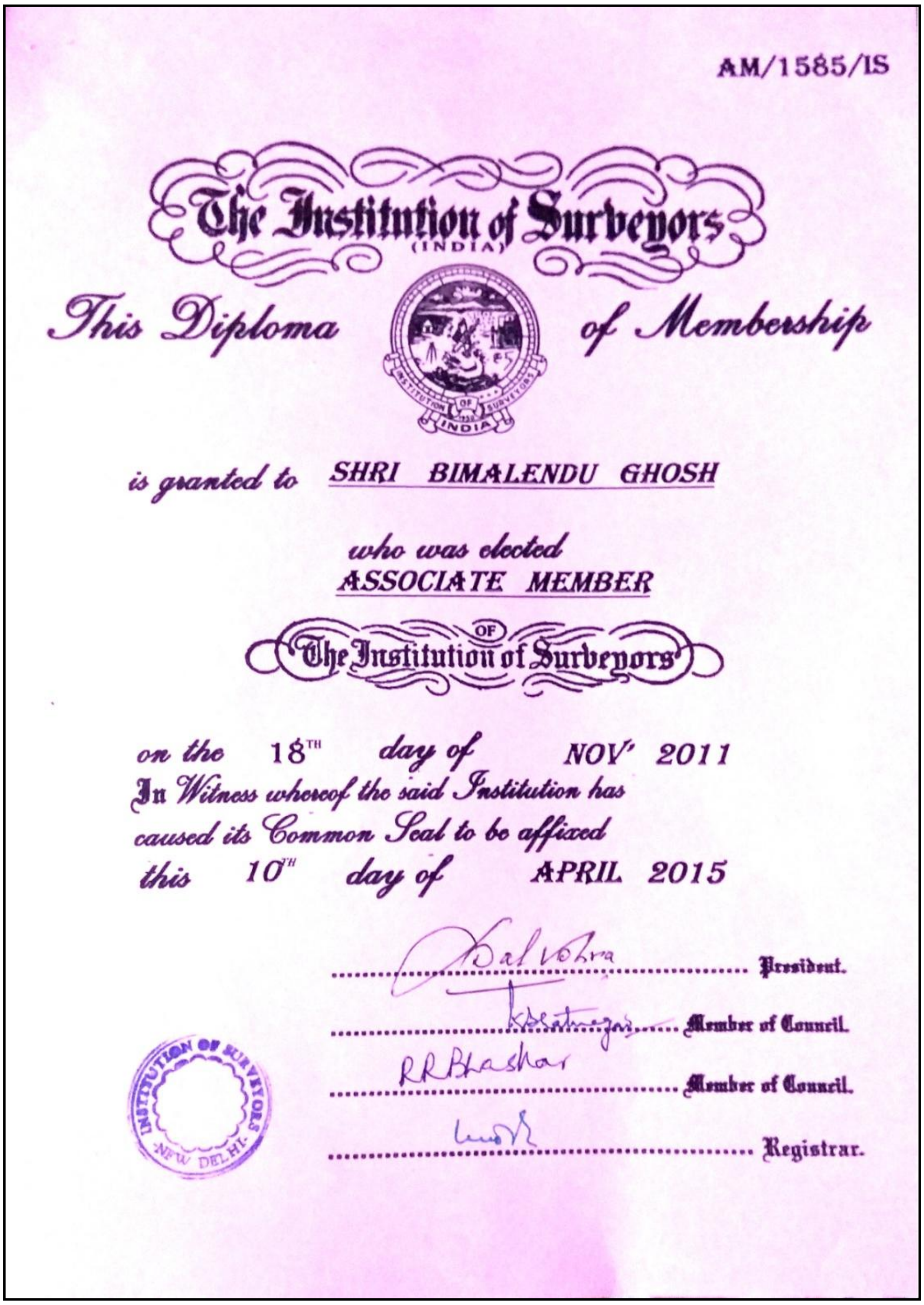
21.3 Certificate of Bimalendu Ghosh:-



AM/1585/IS

The Institution of Surveyors (INDIA)

This Diploma of Membership

is granted to SHRI BIMALENDU GHOSH

who was elected ASSOCIATE MEMBER

of The Institution of Surveyors

on the 18TH day of NOV' 2011

In Witness whereof the said Institution has caused its Common Seal to be affixed this 10TH day of APRIL 2015

.... President.

.... Member of Council.

.... Member of Council.

.... Registrar.

21.4 Certificate of Apurban Mukherjee:-

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी

विद्या परिषद की अनुशंसा पर

सिविल अभियांत्रिकी में

प्रौद्योगिकी निष्णात की उपाधि

(विशेषज्ञता: वॉटर रिसोर्सेज़: युटिलाइजेशन ऐण्ड एनवाइरॉन्मेंटेल मैनेजमेंट)

अपरुबन मुखर्जी

को इस उपाधि के प्रदान हेतु विनियम विहित अपेक्षाएँ मई 2006 में सफलतापूर्वक पूर्ण करने पर प्रदान करता है।

भारतीय गणराज्य के अंतर्गत गुवाहाटी में आज 25 मई 2007 को संस्थान की यह मुद्रा अंकित उपाधि दी गई।

INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

upon the recommendation of the Senate hereby confers the degree of

Master of Technology

in

Civil Engineering

(Specialisation: Water Resources : Utilisation and Environmental Management)

on

Apruban Mukherjee

who has successfully completed in May 2006 the requirements prescribed under the regulations for the award of this degree.

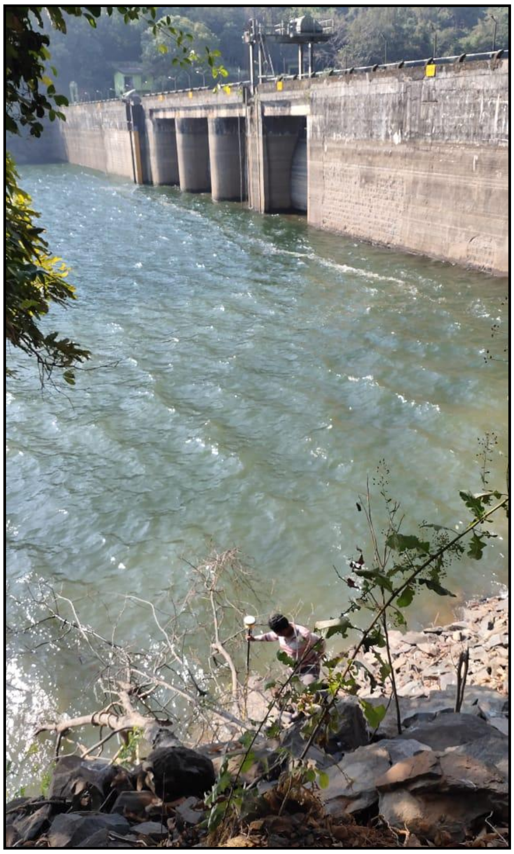
Given this day, under the seal of the Institute at Guwahati in the Republic of India, the 25th day of May, 2007.

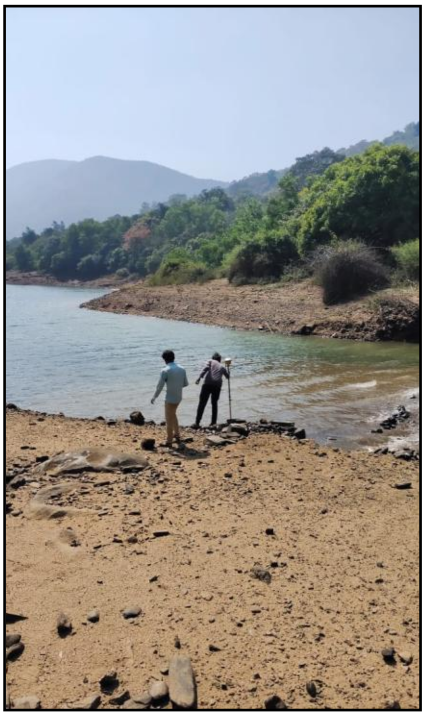
निदेशक एवं अध्यक्ष, विद्या परिषद Director and Chairman, Senate	कुलसचिव Registrar	अध्यक्ष, शासी मंडल Chairman, Board of Governors

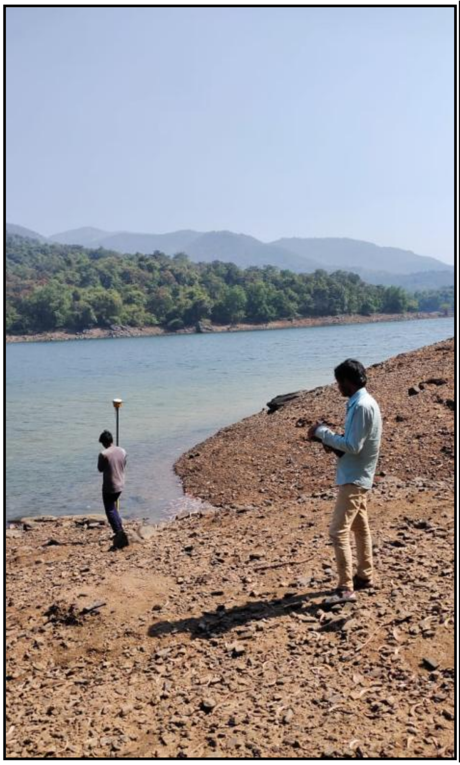
Advance Land & Hydrography Survey India Pvt. Ltd.
P.O.-Bankra
P.S.-Domjur
Howrah
711403

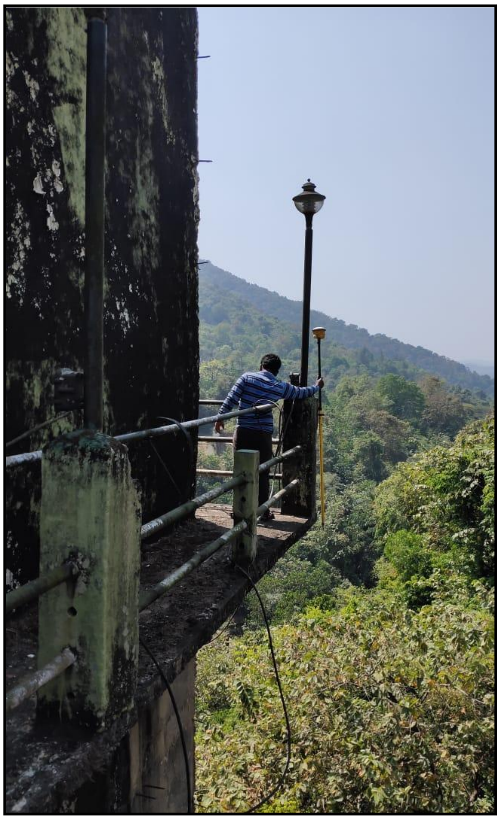
SITE IMAGES

22.0 Site Images:-









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23.0 Deliverable Drawings:-

All the drawings of the dam are enclosed as **Annexure-I:-**