**DAMODAR VALLEY CORPORATION**
**HYDRAULIC DATA DIVISION**
**P.O-MAITHON DAM, DIST-DHANBAD, JHARKHAND**
**PIN-828207**

# "Sedimentation Survey Report of Maithon Reservoir under NHP"


## Precision Survey Consultancy,

**"Vichitra" SP -45, (Kolkata West International City)**
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**Howrah – 711 403, WB**

## ACKNOWLEDGEMENT

Precision Survey Consultancy expresses its gratitude to Damodar Valley Corporation (D.V.C), for awarding the work of carrying out **“Sedimentation Survey Report of Maithon Reservoir 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 Chief Engineer (C), DVC, Maithon f**or his guidance and extending all the required support from time to time, in all stages of the project.

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## 1.0 Introduction of Maithon Reservoir:

Maithon derived its name from “Mai Ka Sthan”, meaning the place for the Hindu Goddess Maa Kalyaneshwari. It is located on the banks of river Barakar. The Maithon Reservoir is located about 48 kms from the Coal City of Dhanbad. The Reservoir with an underground power station is one of its kinds in the whole of South East Asia. The lake on which it is built is spread over 65 square kilometers. This was developed by the Damodar Valley Corporation way back in the year 1948.

The Reservoir is about 15712 ft long and about 165 ft long. The underground power station has a capacity to generate around 60,000 KW of electric power. It has been provided with a spillway capacity of above 5, 00,000 cusecs (14160 Cumecs) with 12 no. radial gates 41 feet (12.49 m) wide and 40 feet (12.19 m) height and an additional 18000 Cusecs (510 cumecs) with 5 No. undercluices of size 10 feet x 5.67 feet (3.05 m x 1.70 m). The Maithon Reservoir itself is located on a picturesque landscape amidst a beautiful lake and beautiful green forests.

## 1.1 Location:

Maithon Reservoir across River Barakar is one of the four main Reservoirs of Damodar Valley Corporation. The Damodar Valley is located in Eastern India within Latitude 22$^{0}$20' to 24$^{0}$30' and Longitude 84$^{0}$45'to 88$^{0}$30'. River Damodar is the main river of which Barakar is the principal tributary. The location of Maithon Reservoir is approximately at Latitude 23$^{0}$17' and Longitude 86$^{0}$49' in Dhanbad District of Jharkhand state.

### 1.1.1 Purpose:

The primary purpose of Maithon Reservoir is flood control, Irrigation, power generation and water supply are some of other important purposes.

The Reservoir feeds an underground power plant with an installed capacity of 60 MW provided by 3 no. horizontal shaft Francis Turbines.

## 1.2 Reservoir Description:

The reservoir had an original water spread area of 6000 acres (2430 hectares) at dead storage level, 17600 acres (7120 hectares) at normal pool level and 26500 acres (10720 hectares) at top of gate levels as per original aerial survey. The reservoir back water extends to about 7 river miles (11.3 km) upstream at dead storage level and 15 river miles (24.1 km) upstream at normal storage level.

Impounding of water started partially during the monsoon of 1955 and regularly since the next monsoon.

## 1.3 Basin Description:

The total catchment area of the Damodar River is about 8500 square miles (22,015 square kilometers) out of which the Barakar commands about 2050 square miles (5309 sq.km) excluding catchment area above an upstream Reservoir at Tilaiya. Total drainage area including Tilaiya catchment is 2430 square miles (6294 sq.km.).

The upper Damodar catchment is fan-shaped and conductive to concentration of floods while the downstream catchment below the Reservoirs constitutes a very narrow strip. The catchment above Maithon Reservoir is generally denuded of forest and vegetal cover. The approximate land is included with Forest area, cultivated land, waste land, villages and tanks etc.

The Land management practice is poor and both sheet and gully erosion are extensively noticeable. As a result, the streams carry appreciable amount of sediment load especially during the monsoons. The principal tributaries of the Barakar are the Usri, the Barsoti and the Irga none of which is controlled.

## 1.4 Hydrology:

The Damodar Valley experiences a well defined monsoon which is normally confined to the period from the middle of June to early October. The annual rainfall of the basin averages to above 50 inches (1270 mm). About 90 to 95 percent of the total annual rainfall occurs during the monsoon when all major floods occur. The volume of flow during the monsoon averages to about 90 percent of the total annual flow. During the dry periods, November to through May, there is extended periods of little or no flow in the main stream and its tributaries.

Heavy rainfall in this region is generally caused during the passage of cyclonic depressions which form at the head of the Bay of Bengal during the monsoon period, June through October, and travel in a north-westerly direction. Sometimes, depressions which form overland also cause intense precipitation.

On an average 3 to 4 such storms form in each of the monsoon months of June to October. Table I shows peak flood and annual monsoon flow data for River Barakar at Maithon Reservoir. The data upto 1957 are based upon river observation and thereafter upon reservoir regulation data.

## 2.0 Description about Sedimentation:-

Reservoir 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 reservoir within 50–200 years. Here, the crucial point is the fact that reservoir 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 Reservoir:-

Trapping sediment behind a Reservoir not only causes sediment to accumulate in the reservoir, 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 Reservoir, the sediments it contains sink to the bottom of the reservoir. The proportion of a river's total sediment load captured by a Reservoir – known as its "trap efficiency" – approaches 100 per cent for many projects, especially those with large reservoirs. As the sediments accumulate in the reservoir, so the Reservoir gradually loses its ability to store water for the purposes for which it was built. Every reservoir 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 Reservoir industry.

The rate of reservoir sedimentation depends mainly on the size of a reservoir relative to the amount of sediment flowing into it: a small reservoir on an extremely muddy river will rapidly lose capacity; a large reservoir on a very clear river may take centuries to lose an appreciable amount of storage. Apart from rapidly filling their reservoirs, sediment–filled rivers also cause headaches for Reservoir operators due to the abrasion of turbines and other Reservoir 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.

## 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 Precision Survey Consultancy:-

Precision Survey Consultancy conducted **"Sedimentation Survey of Maithon Reservoir under NHP" No-M/C&M/NHP/LOA/804 Dated-31.01.2019.**

## 2.4 Weather:-

The survey was undertaken during the month of 'from April to August', 2019. The Temperatures became average for the Topographic survey and Bathymetry Survey.

## 3.0 Project Site Location Map of Maithon Reservoir:-

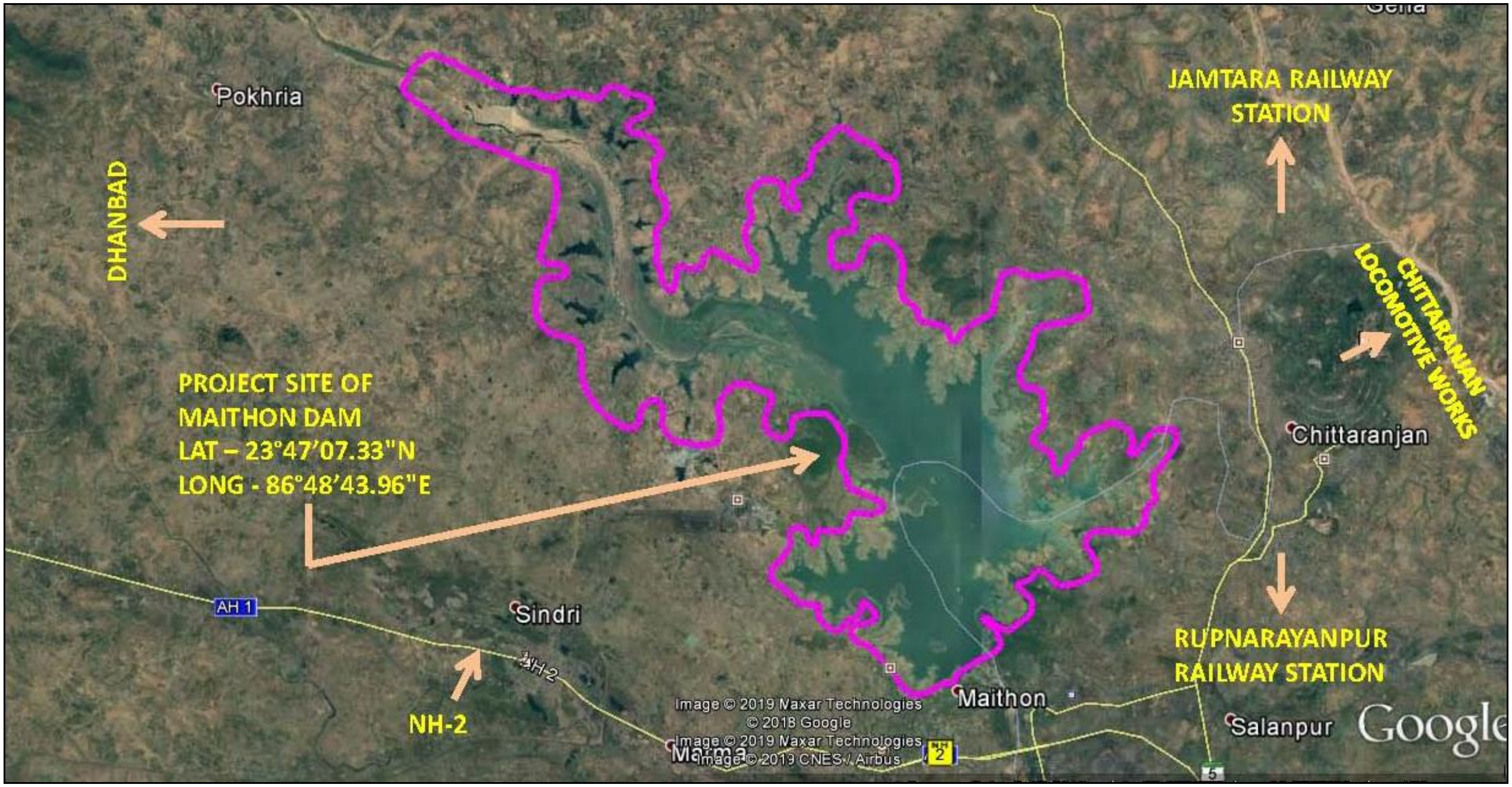


Figure 1-Project site location Map of Maithon Reservoir

## 4.0 Scope of Work:-

The scope of the work includes:-

| Brief Description of the work | Intended Completion period |
|---|---|
| Sedimentation Survey of Maithon Reservoir under NHP No-M/C&M/NHP/LOA/804 Dated-31.01.2019. | |

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 reservoir 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 reservoirs (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 reservoir bed with not less then 10 samples covering the entire area of the reservoir. 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 reservoir as well as accounting for the effect of upstream reservoirs, 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 reservoir, cross sections, L-sections, vertical sediment distribution curve/table, estimation of sedimentation in different zones of reservoirs, mathematical modeling studies etc. keeping in line with the objectives laid down for the study.

g. Preparation of Report containing general information about the reservoir, 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 DVC.

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.

**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 reservoir area under water is covered at 100 m x 100 m grid. For small reservoirs (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 reservoirs (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 reservoir 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 reservoir and balance life of reservoir

Assessment of sediment and its distribution in the reservoir shall be made and likely effects of such sedimentation on the performance of the reservoir shall be assessed. While analyzing the Reservoir 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 reservoir”, C.B.I & P publication on the subject and I.S. 5477 Part-II “Fixing capacities of Reservoirs-Dead storage”.

Separate Chapters are to be included in the report for "Sedimentation Analysis", "Life of Reservoir", "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 reservoir, prediction of sediment distribution etc. Future sediment calculations shall be based on every 10 years block.

iii) Estimation of sedimentation in different zones of reservoir:
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 reservoirs may also be made.

iv) Analysis of Bed material samples
Laboratory analysis of the bed material samples collected from the reservoir 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 DVC.
Officers of DVC shall be trained on the relevant software at Consultants' office for conversion of raw data into analog form during stage-3 analysis part of the survey.

vi) L-section
L-Section of the reservoirs 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 reservoir depth and percent sediment deposited is to be plotted as per IS 5477 PART-II 1994. "Fixing capacities of reservoirs-Dead storage".

viii) Contour map of the reservoir

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 Reservoir

The trap efficiency of reservoir 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 Reservoirs".

x) Charts/drawings for the Report

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

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

### 5.0 Authentic Reference level:-

For the Topographic/Bathymetry Survey, The Level has been carried out from the following positions:-

| Location | Easting (m) | Northing (m) | Latitude (N) | Longitude (E) | Elevation (m) |
|---|---|---|---|---|---|
| Maithon Reservoir | 480948.747 | 2630529.152 | 23°47'09.032" | 86°48'46.803" | 156.905 |

## 6.0 Conduct of survey work

### 6.1 Topographical Survey

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 Maithon reservoir 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** - **MSL**
- **Grid** - **UTM North (45N)**
- **Scale factor** - **As per requirement**

## 6.2 Topographical Survey with GLS 2000 3D Laser Scanner:-

- Speedy, precise scanning with variable range settings
- “Precise Scan Technology II” providing high quality
  Point cloud data with reduced noise
- Full-dome scanning range
- World’s first “Direct Height Measurement
- Easy and accurate registration methods
- Onboard software with intuitive and easy operation

TOF measurement, with quality data with less noise, is further enhanced with ultra high speed direct sampling technology, resulting in quick and accurate measurement. With the GLS-2000, true high-speed laser scanning is realized. The GLS-2000 can provide stress-free measurement throughout an entire project with increased productivity and high efficiency. The GLS-2000 provides a wide range of measuring modes to accommodate different job site demands to achieve accurate measurement and increased productivity regardless of site conditions. Distance measuring range is adequately selectable for applications from short distances, such as facility or interior measurement, to as-build measurement in civil engineering sites and for larger structures.


Figure 2- Topographical Survey with GLS 2000 3D Laser Scanner

## 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:-

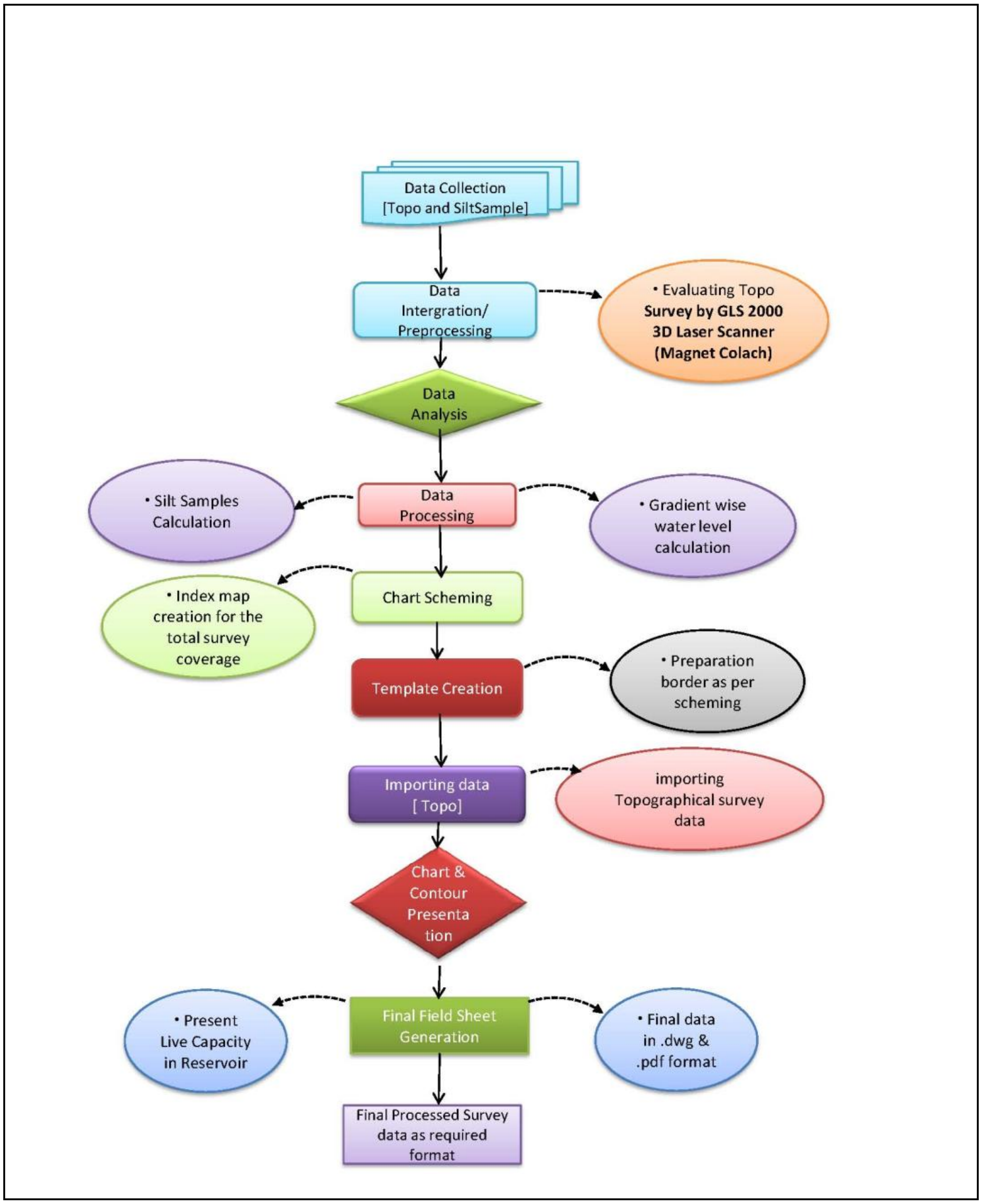


Table 1-Data Processing

### 8.0 Hydrography Survey:-

Bathy 500 MF was used to obtain soundings onboard the survey boat. A working frequency of 210 KHz was used for sounding operations. The digital output from the echo sounder was automatically fed to the HYPACK data logging software on a real-time basis for the acquisition of survey data. No breakdown of equipment was reported and the performance of the equipment was found to be satisfactory during the entire duration of the survey.
The sound velocity was set to 1500 m/s on single beam echo sounder during acquisition by the Bar check procedure method. The Daily bar checks were done prior to the sounding operation and before the closing of the sounding operation for the day. Being very shallow depths, the echo sounder depths were also cross-checked in between by using demarcated sounding poles during the conduct of the survey. The sounding lines were run using Survey boat to identify the design line of the Maithon Reservoir for the possible stretch. The cross lines were run perpendicular to the orientation of Canal flow (i.e. perpendicular to the orientation of depth contours) in respective stretches. The spot sounding was also carried out in the area where the survey boat cannot be operated due to low depth. The hemisphere DGPS and Sounding Pole were used for Spot sounding at shallow locations in the Maithon Reservoir. The DGPS position along with water depths was recorded simultaneously and the tidal reduction was applied to the obtained depths.

**Bathy- 500MF Echo Sounder:** The Bathy-500MF Echo Sounder is an electronic hydrographic survey instrument used for measuring depths with precision chart recordings and digital data output manufactured by SyQuest incorporated, USA. The Bathy-500 echo sounding systems are based on the principle that when a sound signal is sent into the water it will be reflected back when it strikes an object. The Bathy-500 is technologically sophisticated, utilizing modern, micro processor based electronics and a thermal chart recorder mechanism. Digital processing enables the instrument to offer fully automatic digitizing capabilities. When interfaced to a NMEA 0183 compatible position sensor, it provides user with a complete, integrated hydrographic survey environment. The instrument front panel consists of a high contrast, backlit four line LCD displays and a fully sealed input keypad. The front panel encompassing system data, status and setup parameters with RS232/RS422 output format. All operating functions are set via the front panel interface. Setup selections are stored within internal, non-volatile memory for instant availability upon power-up. The instrument decodes and processes the NMEA 0183 formatted sentence GGA or GLL from GPS/DGPS using variable Baud rates for communication.

## 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. **Bathy 500MF** was used to obtain soundings on board the survey launches. A working frequency of 210 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 reservoir have constantly been monitored (manually from outside reservoir) 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 3-During the Hydrography Survey in Maithon Reservoir

## 8.2 Hydrography Survey Process:-

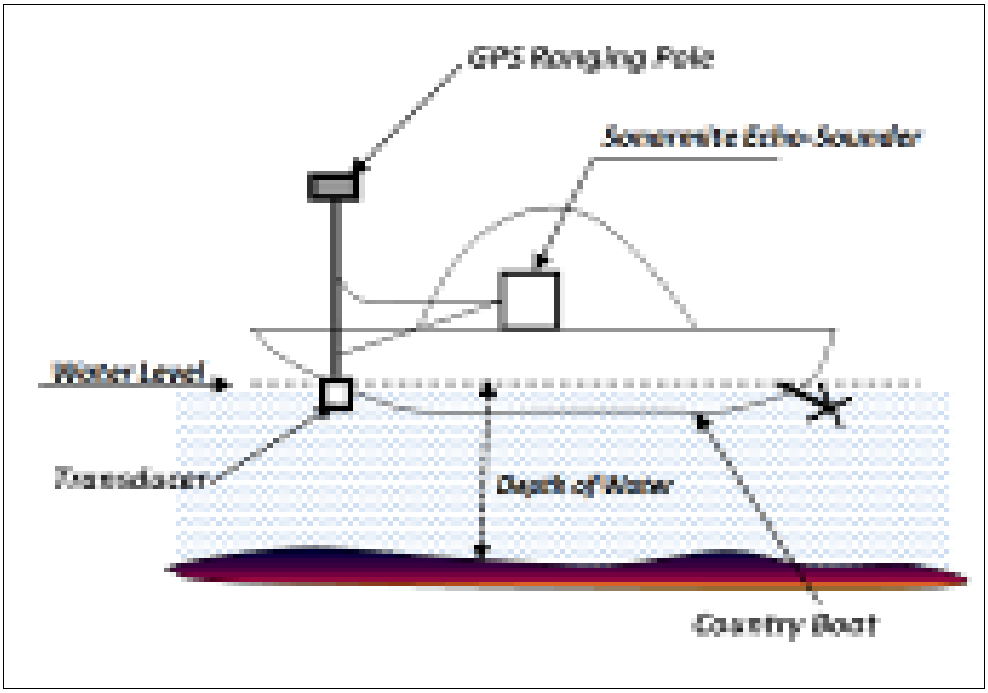


Figure 4-Schematic diagram showing the sequence of operation

## 8.3 Hypack Data Processing System:-

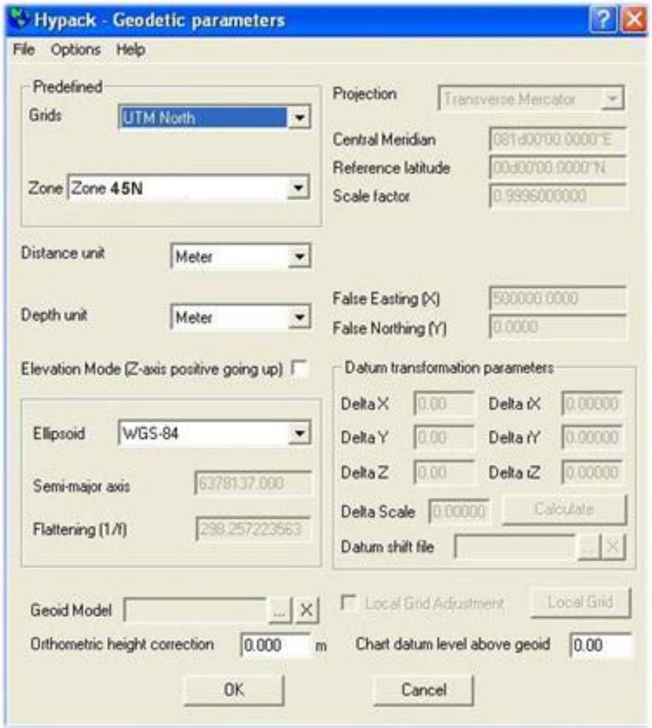


Figure 5-Hypack Data Logging, Geodetic Parameters

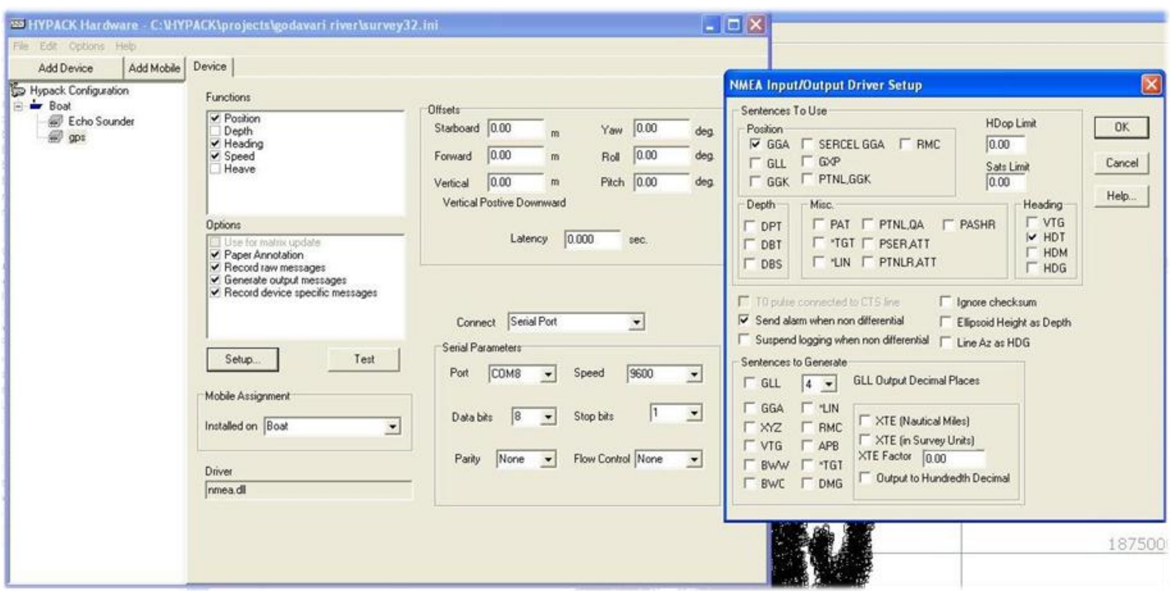


Figure 6-Hypack Data logging, Navigation I/P settings

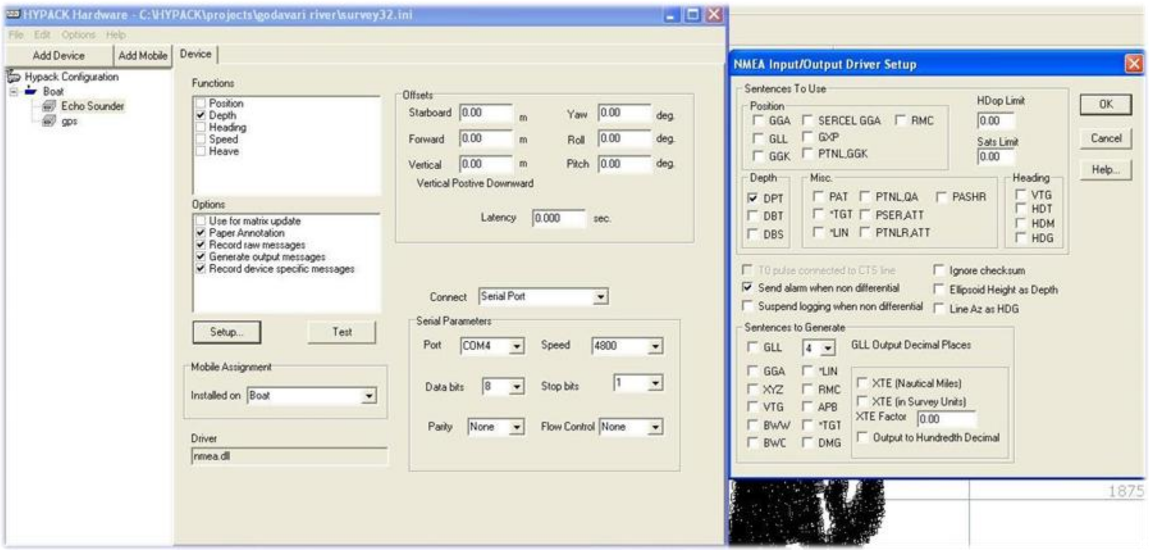


Figure 7-Hypack Data Logging, Echo-sounder I/P settings

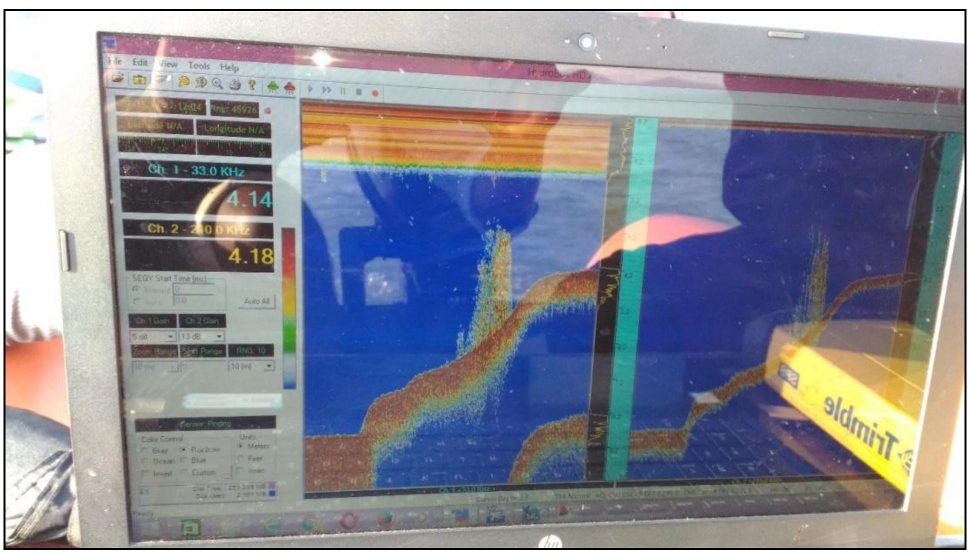


Figure 8-Hypack data processing

## 9.0 Soil Sample Position:-

The Soil samples are collected 10 nos of various locations from Maithon Reservoir which are tabulated below. The location map of soil samples are also indicate at page no-22 with the same Coordinate.

| Sample No | Chainage (km) | Northing (m) | Easting (m) | Latitude (N) | Longitude (E) |
|---|---|---|---|---|---|
| 1 | 0.15 | 2630569.74 | 480771.25 | 23°47'10.344" | 86°48'40.529" |
| 2 | 1.00 | 2631044.09 | 479847.47 | 23°47'25.727" | 86°48'07.863" |
| 3 | 2.00 | 2632674.08 | 478368.66 | 23°48'18.66" | 86°47'15.52" |
| 4 | 4.00 | 2633433.93 | 481513.56 | 23°48'43.51" | 86°49'6.63" |
| 5 | 5.21 | 2634398.54 | 479963.15 | 23°49'14.809" | 86°48'11.786" |
| 6 | 7.81 | 2636963.00 | 479830.00 | 23°50'38.19" | 86°48'6.95" |
| 7 | 12.30 | 2639135.96 | 475516.21 | 23°51'48.60" | 86°45'34.32" |
| 8 | 18.70 | 2643020.00 | 471494.00 | 23°53'54.69" | 86°43'11.84" |
| 9 | 20.00 | 2645316.74 | 467119.89 | 23°55'9.04" | 86°40'36.93" |
| 10 | 22.00 | 2647000.00 | 463975.00 | 23°56'3.55" | 86°38'45.57" |

Table 2-Soil sample positions

9.1 Google image of Soil Sample locations:-

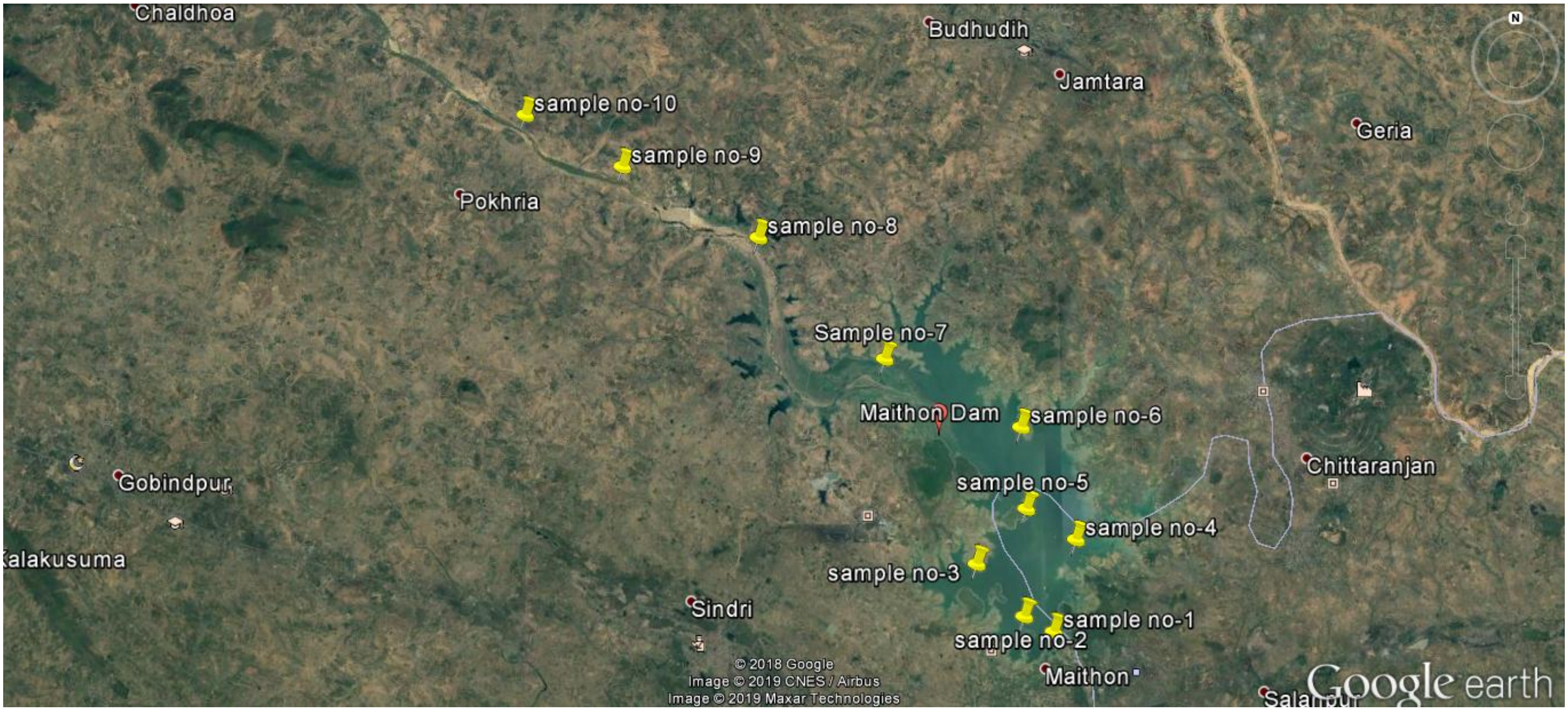


Figure 9-Soil sample locations

## 10.0 Salient Features of Maithon Reservoir:-

| Salient Features of Maithon Reservoir, DVC | | |
|---|---|---|
| General | Inauguration | 27.09.1957 |
| | River | Barakar |
| | District | Dhanbad |
| | State | Jharkhand |
| | | |
| Hydrological | Catchment Area($km^2$) | 6293 |
| | Avg. Annual Precipitation (cm) | 114 |
| | Avg Annual runoff (MCM) | 2700 |
| | | |
| Structural | Type | Composite 1 |
| | Maximum Height above foundation (m) | 56.08 |
| | Type of Spillway | ogee |
| | Crest gate type | Tainter |
| | Crest gate Number | 12 |
| | Crest gate size (mxm) | 12.19x12.5 |
| | Undersluice type | vertical lift |
| | Undersluice Number | 5 |
| | Undersluice size (mxm) | 1.73x3.05 |
| | | |
| Reservoir | Dead storage level (m) above MSL | 132.59 |
| | Dead storage (MCM) | 93 |
| | Conservation level (m) above MSL | 146.31 |
| | Conservation Storage (MCM) | 441 |
| | Max. Utilizable Flood Management level (m) above MSL | 150.9 |
| | Flood Management storage (MCM) | 334 |
| | | |
| Power | Installed Capacity | Horizontal Shaft Francis |
| | Type of Turbine | 63.5 MW |
| | Maximum Head | 38.71 |

Table 3- Salient features of Maithon Reservoir

## 11.0 Survey Equipments:-

| SERIAL NO. | EQUIPMENT NAME | MODEL NO. |
|---|---|---|
| 1 | ECHO SOUNDER | BATHY-500 MF (SYQWEST) |
| 2 | BEACON RECEIVER | TRIMBLE SPS-361 |
| 3 | DGPS | TRIMBLE SPS-986 |
| 4 | DGPS | SP-80 |
| 5 | GLS 2000 3D LASER SCANNER | TOPCON |
| 6 | SOIL SAMPLER | VANVEEN GRAB |
| 7 | HYPACK NAVIGATION SOFTWARE | VERSION-19 |
| 8 | AUTOCAD/CIVIL 3D | 2015 |
| 9 | MICROSOFT OFFICE | 2015 |

Table 4- Details of equipment lists

- Positioning System:-

Figure 10- DGPS Survey Instrument

- 1 no Trimble DGPS system (SPS361)

- 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. Bathy 500MF multi frequency Echo sounder
  - 1 no. transducer 210 kHz + mounting bracket & base plate

Figure 11- Echo Sounder Instrument

- 1no GLS 2000 3DTopcon laser Scanner:-


- 1no Soil Sampler (Van veen grab):-

## 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:-

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 | : | PRECISION SURVEY CONSUTLANCY |
| ADDRESS | : | Vichitra SP-45, KWIC<br>Bankra, P.S.- Domjur, Dist. –Howrah,<br>Pin: 711 403 (W.B) |
| INSTRUMENT | : | ECHO –SOUNDER |
| SERIES | : | SONARMITE |
| SERIAL NUMBER | : | 20114 |
| CALIBRATION DATE | : | 18/11/2018 |
| VALIDITY | : | 17/11/2019 |

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.**

M 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 12-Sonarmite Echo-Sounder Calibration Certificate

## 12.2 RTK –Spectra Precision SP-80:-

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 | : | PRECISION SURVEY CONSUTLANCY |
| ADDRESS | : | Vichitra –SP-45, KWIC, NH-6 Crossing, P.O. –Bankra, P.S.-Domjur, Dist. –Howrah Pin: 711 403 |
| INSTRUMENT | : | GNSS Receiver |
| SERIES | : | SP-80 - Spectra Precision |
| SERIAL NUMBER | : | 5508550620, 5509550021 |
| CALIBRATION DATE | : | 22/11/2018 |
| VALIDITY | : | 22/11/2019 |

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.**

M 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 13-Spectra Precision SP-80Calibration Certificate

## 12.3 G.P.S Beacon Calibration SPS-361:-

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 | : | PRECISION SURVEY CONSUTLANCY |
| ADDRESS | : | Vichitra SP-45, KWIC<br>Bankra, P.S.- Domjur, Dist. –Howrah,<br>Pin: 711 403 (W.B) |
| INSTRUMENT | : | DGPS EQUIPMENT |
| SERIES | : | SPS-361 |
| SERIAL NUMBER | : | 5308K59587 |
| CALIBRATION DATE | : | 02/01/2019 |
| VALIDITY | : | 02/01/2020 |

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.**

M 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 14-Calibration Certificate of SPS-361

## 12.4 Calibration Certificate of GLS-2000 Laser Scanner:-

SOKKIA

Certificate No: SI/N/CA2019003
Sokkia Accredited Service Centre ID No. 20690

### CALIBRATION CERTIFICATE

**(In Accordance with JSIMA)**

| | | |
|---|---|---|
| **Instrument Type** | : | **Laser Scanner** |
| **Model** | : | **GLS-2000** |
| **Serial No.** | : | **TX0320** |
| **Calibration Date** | : | **30TH January 2019** |
| **Due Date** | : | **30TH January 2020** |
| **Validity** | : | **12 Months** |

**Topcon Sokkia India Pvt Ltd.** 'Service Centre' hereby certifies that the instrument has been inspected and calibrated in accordance with the requirement of Japanese Manufacturer Association Standard.

The equipment mentioned above meets the specification and the results comply with the user manual.

**For Topcon Sokkia India Pvt Ltd.**

**Suraj Joshwal**
**Asst. Manager – Service & QA**

SOKKIA INDIA PVT LTD. SERVICE CENTRE

*Topcon Sokkia India Pvt Ltd, Unit No. 101 to 106A, 1st Floor, ABW Tower,*
*M G Road, Sector-25, IFFCO Chowk,*
*Gurgaon, Haryana-122001,*
*Phone: (91) 124-4847676 mail: service@topconsokkia.ind.in*

Figure 15- Calibration Certificate of GLS-2000 Laser Scanner

# 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:-

### 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)

**<u>I.S. 5477 part-II-1994</u>**

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.

| Table : 01 - Detail Analysis of Area Capacity with Elevation Table 2019 | | | | | | |
|---|---|---|---|---|---|---|
| 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 MCM)*** |
| 1 | 113.0 | 0.0 | 31.353 | 0.003 | 0.000 | 0.00 |
| 2 | 113.3 | 0.3 | 123.949 | 0.012 | 23.295 | 0.00 |
| 3 | 113.6 | 0.3 | 216.546 | 0.022 | 51.074 | 0.00 |
| 4 | 113.9 | 0.3 | 309.142 | 0.031 | 78.853 | 0.00 |
| 5 | 114.0 | 0.1 | 401.738 | 0.040 | 35.544 | 0.00 |
| 6 | 114.2 | 0.2 | 76835.508 | 7.684 | 7723.725 | 0.01 |
| 7 | 114.5 | 0.3 | 153269.278 | 15.327 | 34515.718 | 0.04 |
| 8 | 114.8 | 0.3 | 229703.048 | 22.970 | 57445.849 | 0.10 |
| 9 | 115.0 | 0.2 | 306136.818 | 30.614 | 53583.987 | 0.15 |
| 10 | 115.1 | 0.1 | 424870.651 | 42.487 | 36550.373 | 0.19 |
| 11 | 115.4 | 0.3 | 543604.484 | 54.360 | 145271.270 | 0.34 |
| 12 | 115.7 | 0.3 | 662338.317 | 66.234 | 180891.420 | 0.52 |
| 13 | 116.0 | 0.3 | 781072.150 | 78.107 | 216511.570 | 0.73 |
| 14 | 116.3 | 0.3 | 883717.979 | 88.372 | 249718.519 | 0.98 |
| 15 | 116.6 | 0.3 | 986363.807 | 98.636 | 280512.268 | 1.26 |
| 16 | 116.9 | 0.3 | 1089009.636 | 108.901 | 311306.016 | 1.57 |
| 17 | 117.0 | 0.1 | 1191655.464 | 119.166 | 114033.255 | 1.69 |
| 18 | 117.2 | 0.2 | 1296761.142 | 129.676 | 248841.661 | 1.94 |
| 19 | 117.5 | 0.3 | 1401866.820 | 140.187 | 404794.194 | 2.34 |
| 20 | 117.8 | 0.3 | 1506972.498 | 150.697 | 436325.898 | 2.78 |
| 21 | 118.0 | 0.2 | 1612078.176 | 161.208 | 311905.067 | 3.09 |
| 22 | 118.1 | 0.1 | 1709075.960 | 170.908 | 166057.707 | 3.26 |
| 23 | 118.4 | 0.3 | 1806073.744 | 180.607 | 527272.455 | 3.78 |
| 24 | 118.7 | 0.3 | 1903071.527 | 190.307 | 556371.791 | 4.34 |
| 25 | 119.0 | 0.3 | 2000069.311 | 200.007 | 585471.126 | 4.93 |
| 26 | 119.3 | 0.3 | 2143250.377 | 214.325 | 621497.953 | 5.55 |
| 27 | 119.6 | 0.3 | 2286431.442 | 228.643 | 664452.273 | 6.21 |
| 28 | 119.9 | 0.3 | 2429612.508 | 242.961 | 707406.592 | 6.92 |
| 29 | 120.0 | 0.1 | 2572793.573 | 257.279 | 250120.304 | 7.17 |
| 30 | 120.2 | 0.2 | 2697999.890 | 269.800 | 527079.346 | 7.70 |
| 31 | 120.5 | 0.3 | 2823206.206 | 282.321 | 828180.914 | 8.52 |
| 32 | 120.8 | 0.3 | 2948412.523 | 294.841 | 865742.809 | 9.39 |

| Table : 01 - Detail Analysis of Area Capacity with Elevation Table 2019 | | | | | | |
|---|---|---|---|---|---|---|
| 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 MCM)* |
| 33 | 121.0 | 0.2 | 3073618.839 | 307.362 | 602203.136 | 9.99 |
| 34 | 121.1 | 0.1 | 3189819.589 | 318.982 | 313171.921 | 10.31 |
| 35 | 121.4 | 0.3 | 3306020.338 | 330.602 | 974375.989 | 11.28 |
| 36 | 121.7 | 0.3 | 3422221.088 | 342.222 | 1009236.214 | 12.29 |
| 37 | 122.0 | 0.3 | 3538421.837 | 353.842 | 1044096.439 | 13.33 |
| 38 | 122.3 | 0.3 | 3647223.642 | 364.722 | 1077846.822 | 14.41 |
| 39 | 122.6 | 0.3 | 3756025.447 | 375.603 | 1110487.363 | 15.52 |
| 40 | 122.9 | 0.3 | 3864827.251 | 386.483 | 1143127.905 | 16.66 |
| 41 | 123.0 | 0.1 | 3973629.056 | 397.363 | 391922.815 | 17.06 |
| 42 | 123.2 | 0.2 | 4116468.061 | 411.647 | 809009.712 | 17.87 |
| 43 | 123.5 | 0.3 | 4259307.066 | 425.931 | 1256366.269 | 19.12 |
| 44 | 123.8 | 0.3 | 4402146.070 | 440.215 | 1299217.970 | 20.42 |
| 45 | 124.0 | 0.2 | 4544985.075 | 454.499 | 894713.115 | 21.32 |
| 46 | 124.1 | 0.1 | 4708551.897 | 470.855 | 462676.849 | 21.78 |
| 47 | 124.4 | 0.3 | 4872118.718 | 487.212 | 1437100.592 | 23.22 |
| 48 | 124.7 | 0.3 | 5035685.540 | 503.569 | 1486170.639 | 24.70 |
| 49 | 125.0 | 0.3 | 5199252.361 | 519.925 | 1535240.685 | 26.24 |
| 50 | 125.3 | 0.3 | 5393749.778 | 539.375 | 1588950.321 | 27.83 |
| 51 | 125.6 | 0.3 | 5588247.195 | 558.825 | 1647299.546 | 29.47 |
| 52 | 125.9 | 0.3 | 5782744.612 | 578.274 | 1705648.771 | 31.18 |
| 53 | 126.0 | 0.1 | 5977242.029 | 597.724 | 587999.332 | 31.77 |
| 54 | 126.2 | 0.2 | 6191603.421 | 619.160 | 1216884.545 | 32.98 |
| 55 | 126.5 | 0.3 | 6405964.813 | 640.596 | 1889635.235 | 34.87 |
| 56 | 126.8 | 0.3 | 6620326.204 | 662.033 | 1953943.653 | 36.83 |
| 57 | 127.0 | 0.2 | 6834687.596 | 683.469 | 1345501.380 | 38.17 |
| 58 | 127.1 | 0.1 | 7072113.258 | 707.211 | 695340.043 | 38.87 |
| 59 | 127.4 | 0.3 | 7309538.921 | 730.954 | 2157247.827 | 41.03 |
| 60 | 127.7 | 0.3 | 7546964.583 | 754.696 | 2228475.525 | 43.25 |
| 61 | 128.0 | 0.3 | 7765584.007 | 776.558 | 2296882.288 | 45.55 |
| 62 | 128.3 | 0.3 | 7987837.629 | 798.784 | 2363013.245 | 47.91 |
| 63 | 128.6 | 0.3 | 8210091.250 | 821.009 | 2429689.332 | 50.34 |
| 64 | 128.9 | 0.3 | 8432344.872 | 843.234 | 2496365.418 | 52.84 |
| 65 | 129.0 | 0.1 | 8506429.412 | 850.643 | 846938.714 | 53.69 |
| 66 | 129.2 | 0.2 | 8731844.844 | 873.184 | 1723827.426 | 55.41 |
| 67 | 129.5 | 0.3 | 9069967.993 | 906.997 | 2670271.926 | 58.08 |

| Table : 01 - Detail Analysis of Area Capacity with Elevation Table 2019 | | | | | | |
|---|---|---|---|---|---|---|
| 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 MCM)* |
| 68 | 129.8 | 0.3 | 9408091.142 | 940.809 | 2771708.870 | 60.85 |
| 69 | 130.0 | 0.2 | 9633506.574 | 963.351 | 1904159.772 | 62.76 |
| 70 | 130.1 | 0.1 | 9652557.837 | 965.256 | 964303.221 | 63.72 |
| 71 | 130.4 | 0.3 | 9709711.626 | 970.971 | 2904340.419 | 66.63 |
| 72 | 130.7 | 0.3 | 9766865.414 | 976.687 | 2921486.556 | 69.55 |
| 73 | 131.0 | 0.3 | 9824019.203 | 982.402 | 2938632.693 | 72.49 |
| 74 | 131.3 | 0.3 | 10133959.977 | 1013.396 | 2993696.877 | 75.48 |
| 75 | 131.6 | 0.3 | 10443900.751 | 1044.390 | 3086679.109 | 78.57 |
| 76 | 131.9 | 0.3 | 10753841.526 | 1075.384 | 3179661.342 | 81.75 |
| 77 | 132.0 | 0.1 | 10857155.117 | 1085.716 | 1080549.832 | 82.83 |
| 78 | 132.2 | 0.2 | 11373496.502 | 1137.350 | 2223065.162 | 85.05 |
| 79 | 132.5 | 0.3 | 12148008.580 | 1214.801 | 3528225.762 | 88.58 |
| 80 | 132.6 | 0.1 | 12406179.272 | 1240.618 | 1227709.393 | 89.80 |
| 81 | 132.8 | 0.2 | 12922520.657 | 1292.252 | 2532869.993 | 92.34 |
| 82 | 133.0 | 0.2 | 13438862.042 | 1343.886 | 2636138.270 | 94.97 |
| 83 | 133.1 | 0.1 | 13597259.846 | 1359.726 | 1351806.094 | 96.33 |
| 84 | 133.4 | 0.3 | 14072453.256 | 1407.245 | 4150456.965 | 100.48 |
| 85 | 133.7 | 0.3 | 14547646.667 | 1454.765 | 4293014.989 | 104.77 |
| 86 | 134.0 | 0.3 | 15022840.078 | 1502.284 | 4435573.012 | 109.20 |
| 87 | 134.3 | 0.3 | 15665122.849 | 1566.512 | 4603194.439 | 113.81 |
| 88 | 134.6 | 0.3 | 16307405.620 | 1630.741 | 4795879.270 | 118.60 |
| 89 | 134.9 | 0.3 | 16949688.391 | 1694.969 | 4988564.102 | 123.59 |
| 90 | 135.0 | 0.1 | 17163782.648 | 1716.378 | 1705673.552 | 125.30 |
| 91 | 135.2 | 0.2 | 17380456.589 | 1738.046 | 3454423.924 | 128.75 |
| 92 | 135.5 | 0.3 | 17705467.500 | 1770.547 | 5262888.613 | 134.02 |
| 93 | 135.8 | 0.3 | 18030478.410 | 1803.048 | 5360391.886 | 139.38 |
| 94 | 136.0 | 0.2 | 18247152.351 | 1824.715 | 3627763.076 | 143.00 |
| 95 | 136.1 | 0.1 | 18479788.347 | 1847.979 | 1836347.035 | 144.84 |
| 96 | 136.4 | 0.3 | 19177696.333 | 1917.770 | 5648622.702 | 150.49 |
| 97 | 136.7 | 0.3 | 19875604.320 | 1987.560 | 5857995.098 | 156.35 |
| 98 | 137.0 | 0.3 | 20573512.307 | 2057.351 | 6067367.494 | 162.41 |
| 99 | 137.3 | 0.3 | 21653230.330 | 2165.323 | 6334011.396 | 168.75 |
| 100 | 137.6 | 0.3 | 22732948.353 | 2273.295 | 6657926.802 | 175.41 |
| 101 | 137.9 | 0.3 | 23812666.375 | 2381.267 | 6981842.209 | 182.39 |
| 102 | 138.0 | 0.1 | 24172572.383 | 2417.257 | 2399261.938 | 184.79 |

| Table : 01 - Detail Analysis of Area Capacity with Elevation Table 2019 | | | | | | |
|---|---|---|---|---|---|---|
| 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 MCM)*** |
| 103 | 138.2 | 0.2 | 24957616.891 | 2495.762 | 4913018.927 | 189.70 |
| 104 | 138.5 | 0.3 | 26135183.654 | 2613.518 | 7663920.082 | 197.36 |
| 105 | 138.8 | 0.3 | 27312750.416 | 2731.275 | 8017190.110 | 205.38 |
| 106 | 139.0 | 0.2 | 28097794.924 | 2809.779 | 5541054.534 | 210.92 |
| 107 | 139.1 | 0.1 | 28677282.991 | 2867.728 | 2838753.896 | 213.76 |
| 108 | 139.4 | 0.3 | 30415747.190 | 3041.575 | 8863954.527 | 222.62 |
| 109 | 139.7 | 0.3 | 32154211.390 | 3215.421 | 9385493.787 | 232.01 |
| 110 | 140.0 | 0.3 | 33892675.590 | 3389.268 | 9907033.047 | 241.92 |
| 111 | 140.3 | 0.3 | 34753078.367 | 3475.308 | 10296863.094 | 252.21 |
| 112 | 140.6 | 0.3 | 35613481.144 | 3561.348 | 10554983.927 | 262.77 |
| 113 | 140.9 | 0.3 | 36473883.920 | 3647.388 | 10813104.760 | 273.58 |
| 114 | 141.0 | 0.1 | 36760684.846 | 3676.068 | 3661728.438 | 277.24 |
| 115 | 141.2 | 0.2 | 37306905.269 | 3730.691 | 7406759.012 | 284.65 |
| 116 | 141.5 | 0.3 | 38126235.904 | 3812.624 | 11314971.176 | 295.97 |
| 117 | 141.8 | 0.3 | 38945566.539 | 3894.557 | 11560770.366 | 307.53 |
| 118 | 142.0 | 0.2 | 39491786.962 | 3949.179 | 7843735.350 | 315.37 |
| 119 | 142.1 | 0.1 | 39774607.542 | 3977.461 | 3963319.725 | 319.33 |
| 120 | 142.4 | 0.3 | 40623069.281 | 4062.307 | 12059651.523 | 331.39 |
| 121 | 142.7 | 0.3 | 41471531.020 | 4147.153 | 12314190.045 | 343.71 |
| 122 | 143.0 | 0.3 | 42319992.759 | 4231.999 | 12568728.567 | 356.28 |
| 123 | 143.3 | 0.3 | 43527393.216 | 4352.739 | 12877107.896 | 369.15 |
| 124 | 143.6 | 0.3 | 44734793.673 | 4473.479 | 13239328.033 | 382.39 |
| 125 | 143.9 | 0.3 | 45942194.130 | 4594.219 | 13601548.170 | 395.99 |
| 126 | 144.0 | 0.1 | 46344660.949 | 4634.466 | 4614342.754 | 400.61 |
| 127 | 144.2 | 0.2 | 47336970.495 | 4733.697 | 9368163.144 | 409.98 |
| 128 | 144.5 | 0.3 | 48825434.815 | 4882.543 | 14424360.796 | 424.40 |
| 129 | 144.8 | 0.3 | 50313899.134 | 5031.390 | 14870900.092 | 439.27 |
| 130 | 145.0 | 0.2 | 51306208.680 | 5130.621 | 10162010.781 | 449.43 |
| 131 | 145.1 | 0.1 | 51689646.489 | 5168.965 | 5149792.758 | 454.58 |
| 132 | 145.4 | 0.3 | 52839959.915 | 5283.996 | 15679440.961 | 470.26 |
| 133 | 145.7 | 0.3 | 53990273.341 | 5399.027 | 16024534.988 | 486.29 |
| 134 | 146.0 | 0.3 | 55140586.767 | 5514.059 | 16369629.016 | 502.66 |
| 135 | 146.3 | 0.3 | 56831123.937 | 5683.112 | 16795756.606 | 519.45 |
| 136 | 146.6 | 0.3 | 58521661.106 | 5852.166 | 17302917.756 | 536.76 |
| 137 | 146.9 | 0.3 | 60212198.276 | 6021.220 | 17810078.907 | 554.57 |

| Table : 01 - Detail Analysis of Area Capacity with Elevation Table 2019 | | | | | | |
|---|---|---|---|---|---|---|
| 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 MCM)* |
| 138 | 147.0 | 0.1 | 60775710.666 | 6077.571 | 6049395.447 | 560.62 |
| 139 | 147.2 | 0.2 | 62107239.246 | 6210.724 | 12288294.991 | 572.90 |
| 140 | 147.5 | 0.3 | 64104532.117 | 6410.453 | 18931765.705 | 591.84 |
| 141 | 147.8 | 0.3 | 66101824.988 | 6610.182 | 19530953.566 | 611.37 |
| 142 | 148.0 | 0.2 | 67433353.568 | 6743.335 | 13353517.856 | 624.72 |
| 143 | 148.1 | 0.1 | 68041653.446 | 6804.165 | 6773750.351 | 631.49 |
| 144 | 148.4 | 0.3 | 69866553.078 | 6986.655 | 20686230.979 | 652.18 |
| 145 | 148.7 | 0.3 | 71691452.711 | 7169.145 | 21233700.868 | 673.41 |
| 146 | 149.0 | 0.3 | 73516352.344 | 7351.635 | 21781170.758 | 695.19 |
| 147 | 149.3 | 0.3 | 75169952.941 | 7516.995 | 22302945.793 | 717.50 |
| 148 | 149.6 | 0.3 | 76823553.539 | 7682.355 | 22799025.972 | 740.30 |
| 149 | 149.9 | 0.3 | 78477154.136 | 7847.715 | 23295106.151 | 763.59 |
| 150 | 150.0 | 0.1 | 79028354.335 | 7902.835 | 7875275.424 | 771.47 |
| 151 | 150.2 | 0.2 | 80232768.048 | 8023.277 | 15926112.238 | 787.39 |
| 152 | 150.5 | 0.3 | 82039388.617 | 8203.939 | 24340823.500 | 811.73 |
| 153 | 150.8 | 0.3 | 83846009.186 | 8384.601 | 24882809.670 | 836.62 |
| 154 | 150.9 | 0.1 | 84448216.043 | 8444.822 | 8414711.261 | 845.03 |

Table 5-Capacity area Table of Maithon Reservoir 2019

# 13.1.1 Area Capacity Curve 2019:-

# Assessment of effects of Sedimentation on performance of Reservoir and balance life of reservoir (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.**

13.2 Assessment of effects of Sedimentation on performance of Reservoir and Balance life of Reservoir (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 Reservoirs". C.B.I & P Publication on the subject and I.S 5477 part-II "Fixing Capacities of Reservoirs – 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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## 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* ).

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.

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.

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.

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 over-come 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 màde.

**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 Reservoir and Balance life of Reservoir (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.

*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 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:

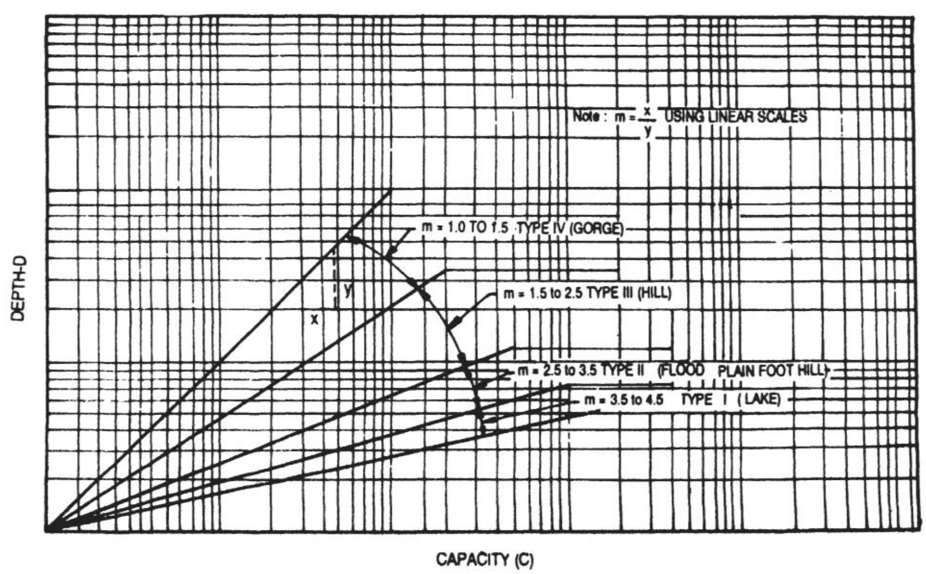
$$A_p = Cp^m (l - p)^n \qquad \text{......(1)}$$

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.



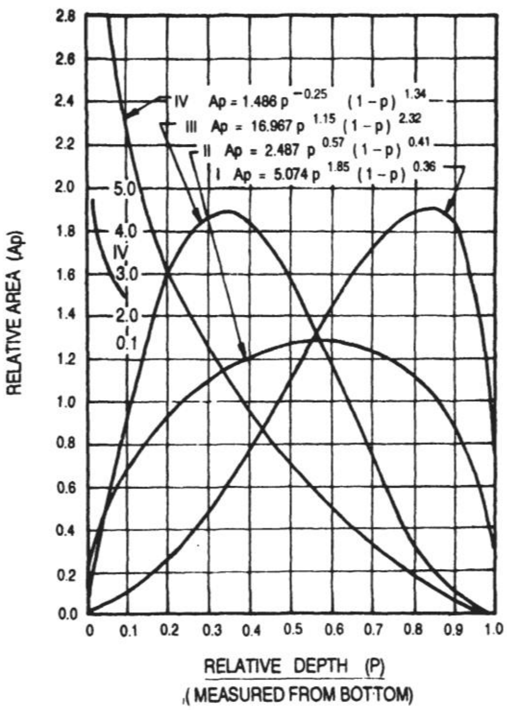



FIG. 2 SEDIMENT DISTRIBUTION – AREA DESIGN CURVES ( BASED ON RESERVOIR STORAGE CURVES )

#### 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.

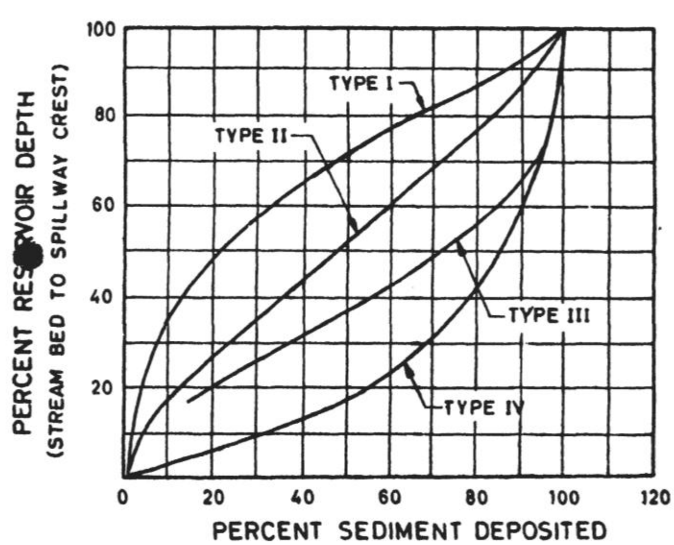
The basic equation in this method is:

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

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 $A_0$ and (b) the portion $V_0$ 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:

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

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

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,

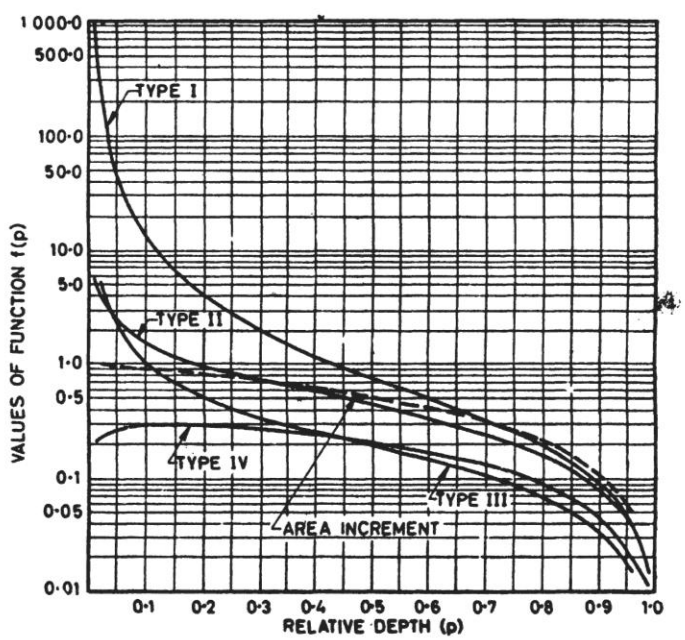
$H$ = the total depth of reservoir for normal water surface in metres, and

$A(pH)$ = 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 ($P_0$) reservoir at new zero elevation after sedimentation. New zero-elevation may be computed by adding the product $P_0 . H$ 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.

**SOFTWARE NAME** - **IBM SPSS STATISTICS (STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES)**

**CURRENT VERSION** - **2015**

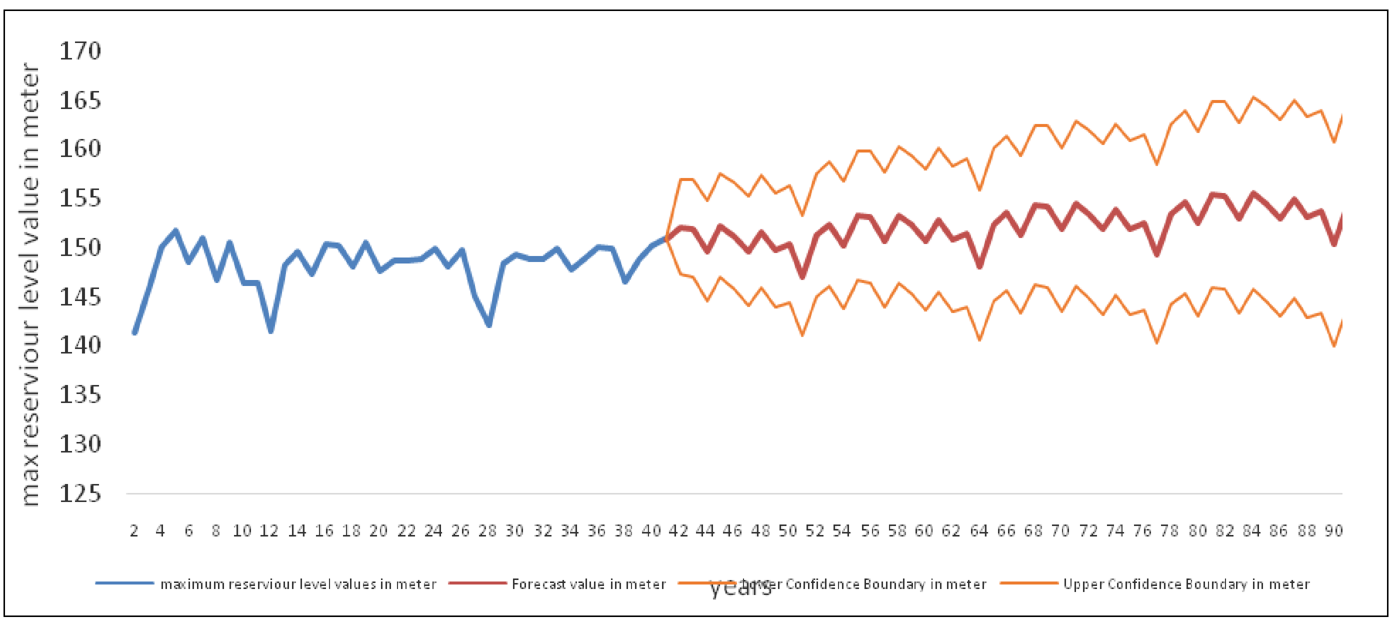
The Mathematical modeling study has been prepared by the above software and this study is completely prepared by Shri Arun Roy.

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

| Timeline (Year) | Values (m) | Forecast (m) | Lower Confidence Bound (m) | Upper Confidence Bound (m) |
|---|---|---|---|---|
| 2 | 141.30 | | | |
| 3 | 145.70 | | | |
| 4 | 150.00 | | | |
| 5 | 151.70 | | | |
| 6 | 148.50 | | | |
| 7 | 150.90 | | | |
| 8 | 146.70 | | | |
| 9 | 150.40 | | | |
| 10 | 146.39 | | | |
| 11 | 146.42 | | | |
| 12 | 141.50 | | | |
| 13 | 148.20 | | | |
| 14 | 149.60 | | | |
| 15 | 147.30 | | | |
| 16 | 150.30 | | | |
| 17 | 150.20 | | | |
| 18 | 148.00 | | | |
| 19 | 150.50 | | | |
| 20 | 147.50 | | | |
| 21 | 148.60 | | | |
| 22 | 148.70 | | | |
| 23 | 148.80 | | | |
| 24 | 149.90 | | | |
| 25 | 148.10 | | | |
| 26 | 149.70 | | | |
| 27 | 144.90 | | | |
| 28 | 142.10 | | | |
| 29 | 148.30 | | | |
| 30 | 149.20 | | | |
| 31 | 148.80 | | | |
| 32 | 148.80 | | | |
| 33 | 149.80 | | | |
| 34 | 147.74 | | | |

| Timeline (Year) | Values (m) | Forecast (m) | Lower Confidence Bound (m) | Upper Confidence Bound (m) |
|---|---|---|---|---|
| 35 | 148.82 | | | |
| 36 | 150.04 | | | |
| 37 | 149.79 | | | |
| 38 | 146.52 | | | |
| 39 | 148.73 | | | |
| 40 | 150.23 | | | |
| 41 | 150.90 | 150.90 | 150.90 | 150.90 |
| 42 | | 152.08 | 147.27 | 156.91 |
| 43 | | 151.94 | 146.98 | 156.92 |
| 44 | | 149.64 | 144.53 | 154.76 |
| 45 | | 152.19 | 146.94 | 157.46 |
| 46 | | 151.18 | 145.78 | 156.59 |
| 47 | | 149.63 | 144.09 | 155.17 |
| 48 | | 151.61 | 145.94 | 157.30 |
| 49 | | 149.73 | 143.92 | 155.55 |
| 50 | | 150.33 | 144.39 | 156.28 |
| 51 | | 147.05 | 140.98 | 153.13 |
| 52 | | 151.21 | 145.01 | 157.42 |
| 53 | | 152.39 | 146.06 | 158.72 |
| 54 | | 150.24 | 143.78 | 156.70 |
| 55 | | 153.18 | 146.61 | 159.77 |
| 56 | | 153.04 | 146.34 | 159.76 |
| 57 | | 150.74 | 143.92 | 157.57 |
| 58 | | 153.29 | 146.35 | 160.25 |
| 59 | | 152.28 | 145.22 | 159.35 |
| 60 | | 150.73 | 143.55 | 157.92 |
| 61 | | 152.72 | 145.42 | 160.02 |
| 62 | | 150.83 | 143.42 | 158.26 |
| 63 | | 151.43 | 143.91 | 158.97 |
| 64 | | 148.16 | 140.51 | 155.81 |
| 65 | | 152.31 | 144.56 | 160.07 |
| 66 | | 153.49 | 145.62 | 161.37 |
| 67 | | 151.34 | 143.36 | 159.33 |
| 68 | | 154.29 | 146.20 | 162.39 |
| 69 | | 154.15 | 145.95 | 162.36 |
| 70 | | 151.84 | 143.53 | 160.16 |
| 71 | | 154.40 | 145.98 | 162.83 |
| 72 | | 153.38 | 144.86 | 161.92 |
| 73 | | 151.83 | 143.20 | 160.48 |

| Timeline (Year) | Values (m) | Forecast (m) | Lower Confidence Bound (m) | Upper Confidence Bound (m) |
|---|---|---|---|---|
| 74 | | 153.82 | 145.08 | 162.57 |
| 75 | | 151.94 | 143.09 | 160.79 |
| 76 | | 152.54 | 143.58 | 161.50 |
| 77 | | 149.26 | 140.20 | 158.33 |
| 78 | | 153.41 | 144.25 | 162.59 |
| 79 | | 154.59 | 145.32 | 163.87 |
| 80 | | 152.44 | 143.07 | 161.82 |
| 81 | | 155.39 | 145.91 | 164.88 |
| 82 | | 155.25 | 145.67 | 164.84 |
| 83 | | 152.95 | 143.26 | 162.64 |
| 84 | | 155.50 | 145.71 | 165.29 |
| 85 | | 154.49 | 144.60 | 164.38 |
| 86 | | 152.94 | 142.95 | 162.93 |
| 87 | | 154.92 | 144.83 | 165.02 |
| 88 | | 153.04 | 142.85 | 163.24 |
| 89 | | 153.64 | 143.35 | 163.94 |
| 90 | | 150.36 | 139.97 | 160.76 |
| 91 | | 154.52 | 144.02 | 165.02 |

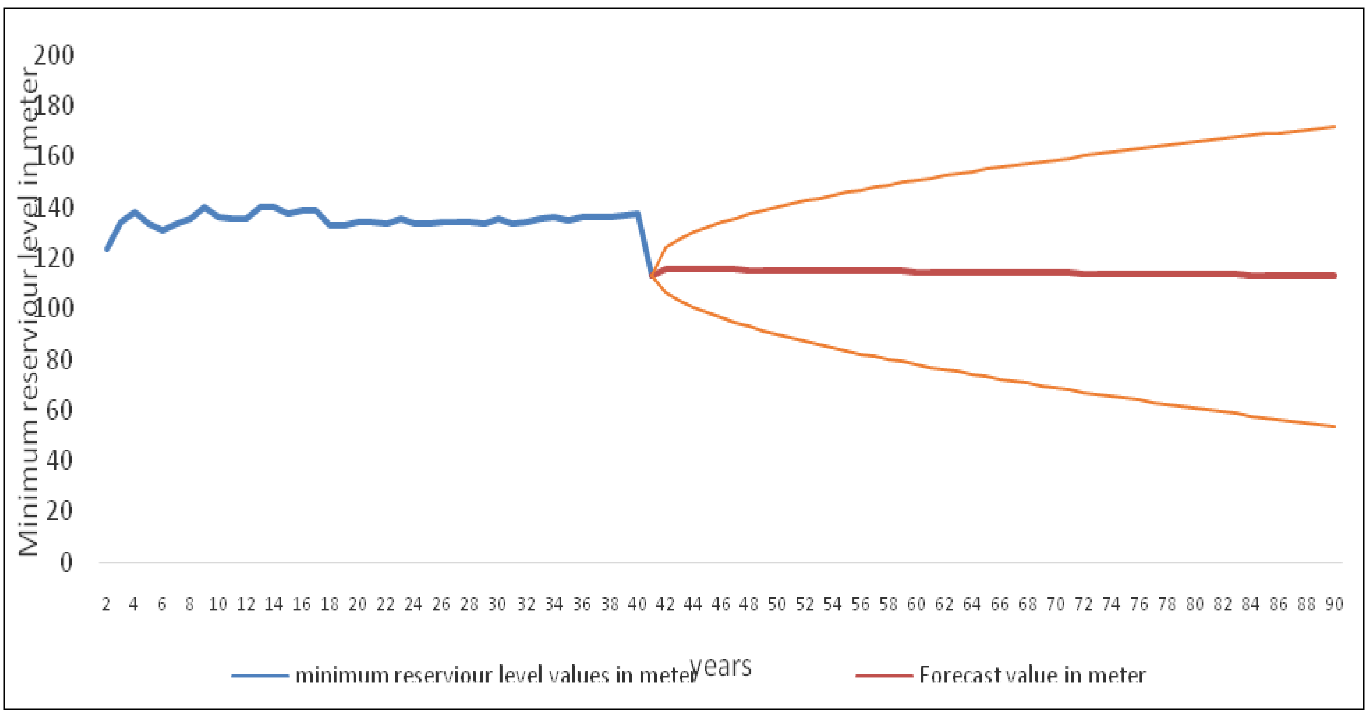


| Timeline (Year) | Values (m) | Forecast (m) | Lower Confidence Bound (m) | Upper Confidence Bound (m) |
|---|---|---|---|---|
| 2 | 123.30 | | | |
| 3 | 133.80 | | | |
| 4 | 137.90 | | | |
| 5 | 133.30 | | | |
| 6 | 131.10 | | | |
| 7 | 133.71 | | | |
| 8 | 135.20 | | | |
| 9 | 140.00 | | | |
| 10 | 136.00 | | | |
| 11 | 135.20 | | | |
| 12 | 135.70 | | | |
| 13 | 139.90 | | | |
| 14 | 140.00 | | | |
| 15 | 137.30 | | | |
| 16 | 138.80 | | | |
| 17 | 138.40 | | | |
| 18 | 133.00 | | | |
| 19 | 132.80 | | | |
| 20 | 134.20 | | | |
| 21 | 134.20 | | | |
| 22 | 133.10 | | | |
| 23 | 135.40 | | | |
| 24 | 133.68 | | | |
| 25 | 133.60 | | | |
| 26 | 133.90 | | | |
| 27 | 134.10 | | | |
| 28 | 134.30 | | | |

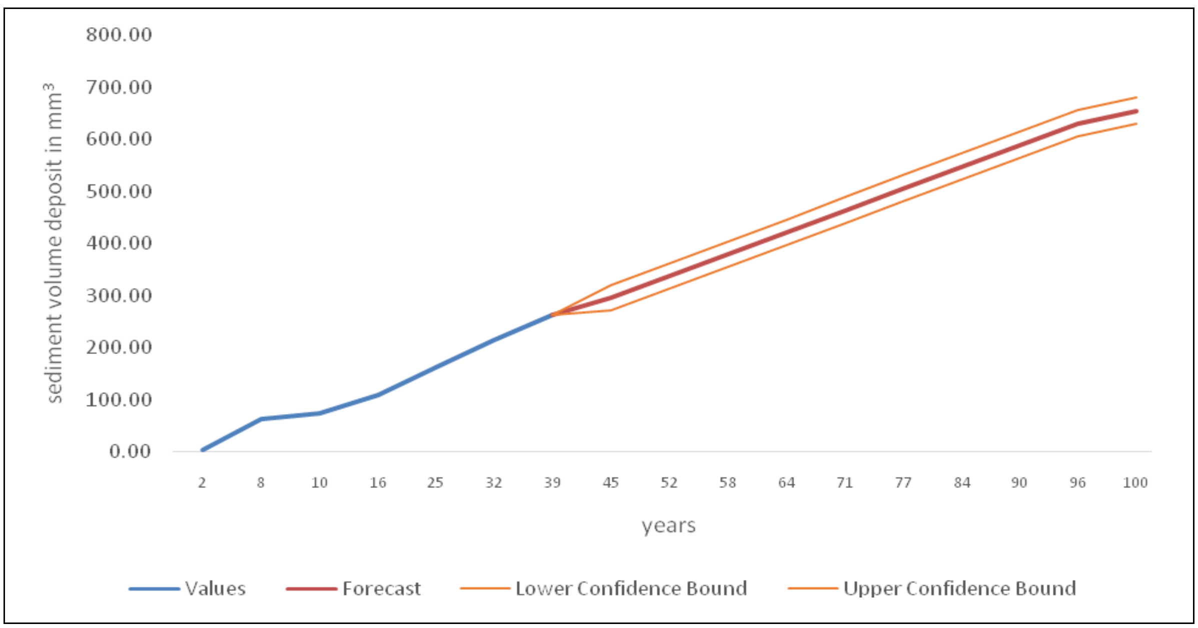
| Timeline (Year) | Values (m) | Forecast (m) | Lower Confidence Bound (m) | Upper Confidence Bound (m) |
|---|---|---|---|---|
| 29 | 133.60 | | | |
| 30 | 135.20 | | | |
| 31 | 133.70 | | | |
| 32 | 134.40 | | | |
| 33 | 135.30 | | | |
| 34 | 136.35 | | | |
| 35 | 134.74 | | | |
| 36 | 135.77 | | | |
| 37 | 135.81 | | | |
| 38 | 135.73 | | | |
| 39 | 136.68 | | | |
| 40 | 137.18 | | | |
| 41 | 113.00 | 113.00 | 113.00 | 113.00 |
| 42 | | 115.35 | 106.23 | 124.48 |
| 43 | | 115.29 | 103.01 | 127.59 |
| 44 | | 115.24 | 100.46 | 130.03 |
| 45 | | 115.19 | 98.26 | 132.12 |
| 46 | | 115.13 | 96.30 | 133.97 |
| 47 | | 115.08 | 94.51 | 135.65 |
| 48 | | 115.02 | 92.86 | 137.19 |
| 49 | | 114.97 | 91.31 | 138.63 |
| 50 | | 114.91 | 89.85 | 139.99 |
| 51 | | 114.86 | 88.45 | 141.27 |
| 52 | | 114.80 | 87.12 | 142.49 |
| 53 | | 114.75 | 85.85 | 143.66 |
| 54 | | 114.69 | 84.62 | 144.78 |
| 55 | | 114.64 | 83.43 | 145.86 |

| Timeline (Year) | Values (m) | Forecast (m) | Lower Confidence Bound (m) | Upper Confidence Bound (m) |
|---|---|---|---|---|
| 56 | | 114.58 | 82.28 | 146.90 |
| 57 | | 114.53 | 81.16 | 147.91 |
| 58 | | 114.48 | 80.08 | 148.88 |
| 59 | | 114.42 | 79.02 | 149.83 |
| 60 | | 114.37 | 77.99 | 150.76 |
| 61 | | 114.31 | 76.98 | 151.66 |
| 62 | | 114.26 | 75.99 | 152.53 |
| 63 | | 114.20 | 75.02 | 153.39 |
| 64 | | 114.15 | 74.07 | 154.23 |
| 65 | | 114.09 | 73.14 | 155.05 |
| 66 | | 114.04 | 72.23 | 155.86 |
| 67 | | 113.98 | 71.33 | 156.65 |
| 68 | | 113.93 | 70.45 | 157.42 |
| 69 | | 113.88 | 69.58 | 158.18 |
| 70 | | 113.82 | 68.72 | 158.93 |
| 71 | | 113.77 | 67.88 | 159.67 |
| 72 | | 113.71 | 67.04 | 160.39 |
| 73 | | 113.66 | 66.22 | 161.10 |
| 74 | | 113.60 | 65.41 | 161.80 |
| 75 | | 113.55 | 64.61 | 162.50 |
| 76 | | 113.49 | 63.82 | 163.18 |
| 77 | | 113.44 | 63.03 | 163.85 |
| 78 | | 113.38 | 62.26 | 164.52 |
| 79 | | 113.33 | 61.50 | 165.17 |
| 80 | | 113.27 | 60.74 | 165.82 |
| 81 | | 113.22 | 59.99 | 166.46 |
| 82 | | 113.17 | 59.25 | 167.09 |

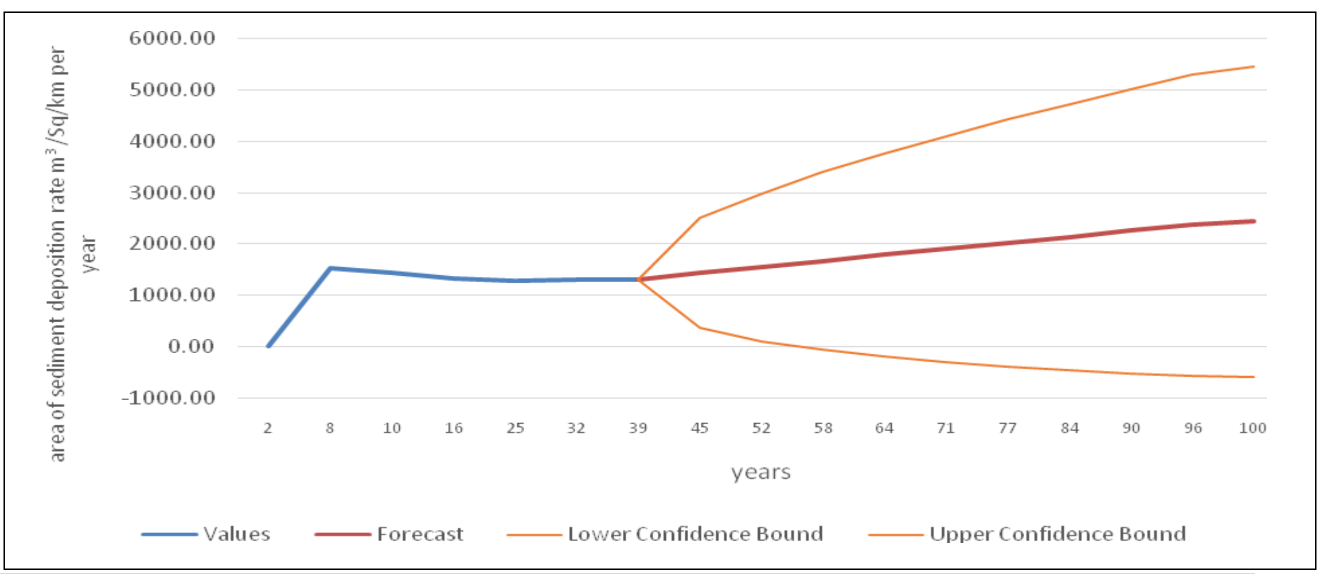
| Timeline (Year) | Values (m) | Forecast (m) | Lower Confidence Bound (m) | Upper Confidence Bound (m) |
|---|---|---|---|---|
| 83 | | 113.11 | 58.51 | 167.72 |
| 84 | | 113.06 | 57.79 | 168.34 |
| 85 | | 113.00 | 57.07 | 168.95 |
| 86 | | 112.95 | 56.35 | 169.55 |
| 87 | | 112.89 | 55.64 | 170.15 |
| 88 | | 112.84 | 54.94 | 170.74 |
| 89 | | 112.78 | 54.25 | 171.33 |
| 90 | | 112.73 | 53.55 | 171.91 |



| Timeline (year) | Values (mm3) | Forecast (mm3) | Lower Confidence Bound (mm3) | Upper Confidence Bound (mm3) |
|---|---|---|---|---|
| 2 | 4.00 | | | |
| 8 | 63.00 | | | |
| 10 | 74.00 | | | |
| 16 | 109.00 | | | |
| 25 | 161.80 | | | |
| 32 | 215.00 | | | |
| 39 | 264.24 | 264.24 | 264.24 | 264.24 |
| 45 | | 297.03 | 272.58 | 321.48 |
| 52 | | 338.82 | 314.37 | 363.27 |
| 58 | | 380.64 | 356.19 | 405.09 |
| 64 | | 422.46 | 398.01 | 446.91 |
| 71 | | 464.28 | 439.83 | 488.73 |
| 77 | | 506.10 | 481.65 | 530.56 |
| 84 | | 547.93 | 523.47 | 572.38 |
| 90 | | 589.75 | 565.29 | 614.20 |
| 96 | | 631.57 | 607.11 | 656.03 |
| 100 | | 655.71 | 631.25 | 680.16 |



| Timeline (Year) | Values (m3/sq km) | Forecast (m3/sq km) | Lower Confidence Bound (m3/sq km) | Upper Confidence Bound (m3/sq km) |
|---|---|---|---|---|
| 2 | 6.00 | | | |
| 8 | 1524.00 | | | |
| 10 | 1429.00 | | | |
| 16 | 1333.00 | | | |
| 25 | 1273.94 | | | |
| 32 | 1290.00 | | | |
| 39 | 1304.00 | 1304.00 | 1304.00 | 1304.00 |
| 45 | | 1433.07 | 363.25 | 2502.88 |
| 52 | | 1550.35 | 110.92 | 2989.77 |
| 58 | | 1667.73 | -64.98 | 3400.44 |
| 64 | | 1785.11 | -198.49 | 3768.72 |
| 71 | | 1902.50 | -304.11 | 4109.11 |
| 77 | | 2019.88 | -389.61 | 4429.38 |
| 84 | | 2137.27 | -459.70 | 4734.24 |
| 90 | | 2254.65 | -517.52 | 5026.82 |
| 96 | | 2372.04 | -565.25 | 5309.33 |
| 100 | | 2439.79 | -588.90 | 5468.48 |



- **Original Allotted Capacity:-**

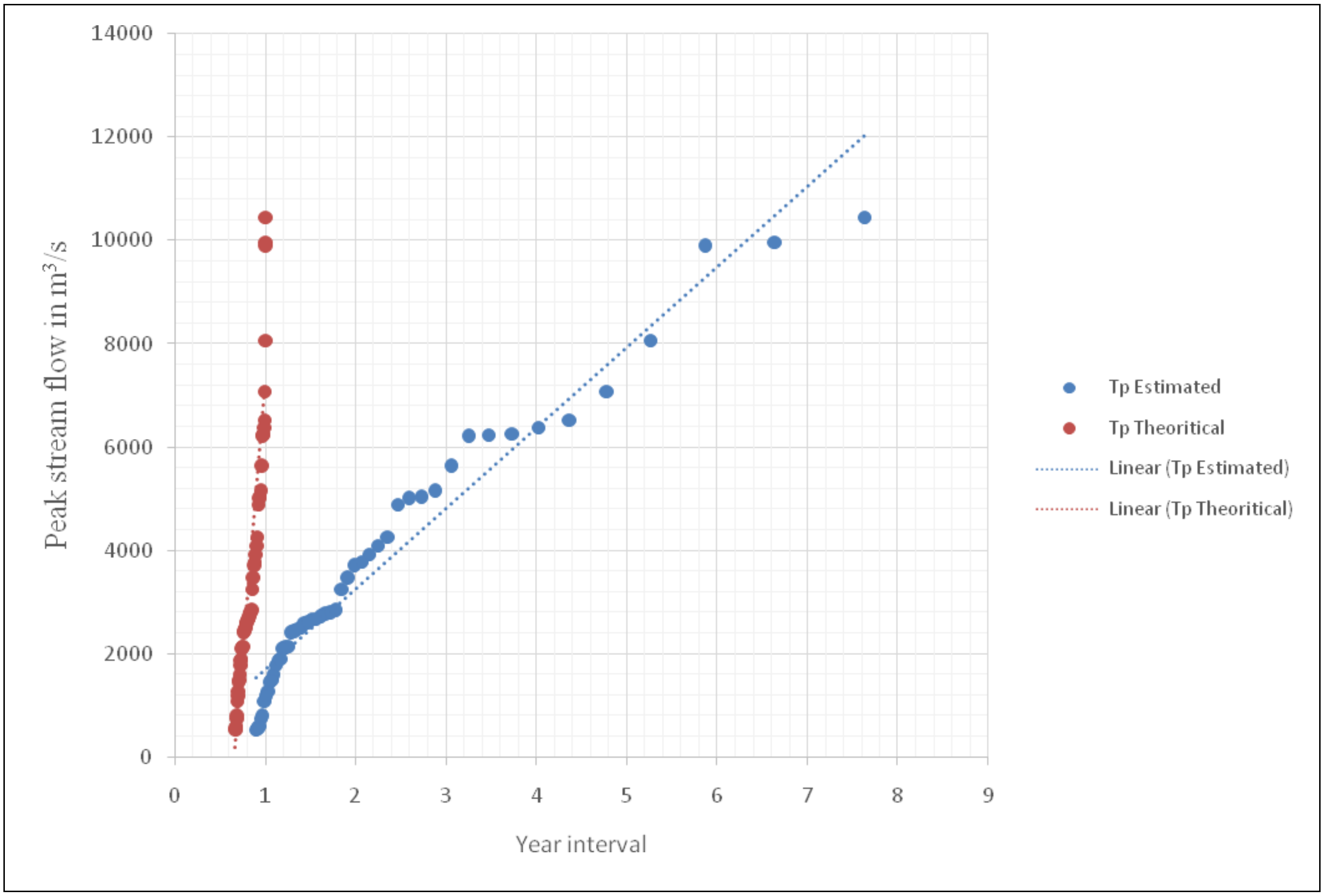
| Storage level | El-From-To | Original Allocated Capacity (MCM) | Original Allocated Capacity (ACRE FT) |
|---|---|---|---|
| Dead Storage | (Upto El.132.6 m) | 206.5 | 167412.27 |
| Live Storage | (El 132.6-146.3m) | 607.3 | 492346.11 |
| Flood Control | (El 146.3-150.90 m) | 382.09 | 309765.40 |
| | Total = | 1195.89 | 969523.79 |

- **Peak Flood and Annual monsoon flow at Maithon Dam:-**

| Year | Annual Peak Stream flow (Cumecs) (m3/s) |
|---|---|
| 1945 | 1885 |
| 1946 | 3907 |
| 1947 | 6220 |
| 1948 | 4885 |
| 1949 | 7079 |
| 1950 | 2403 |
| 1951 | 2655 |
| 1952 | 2836 |
| 1953 | 2767 |
| 1954 | 2119 |
| 1955 | 517 |
| 1956 | 2492 |
| 1957 | 1062 |
| 1958 | 4248 |
| 1959 | 8070 |
| 1960 | 5012 |
| 1961 | 6258 |
| 1962 | 2464 |
| 1963 | 9968 |
| 1964 | 793 |
| 1965 | 5154 |
| 1966 | 736 |
| 1967 | 3710 |
| 1968 | 5635 |
| 1969 | 2718 |
| 1970 | 2124 |
| 1971 | 6226 |

| Year | Annual Peak Stream flow (Cumecs) (m3/s) |
|---|---|
| 1972 | 2095 |
| 1973 | 6513 |
| 1974 | 1586 |
| 1975 | 5040 |
| 1976 | 2577 |
| 1977 | 3766 |
| 1978 | 10448 |
| 1979 | 2435 |
| 1980 | 9912 |
| 1981 | 1265 |
| 1982 | 589 |
| 1983 | 551 |
| 1984 | 6371 |
| 1985 | 3470 |
| 1986 | 2660 |
| 1987 | 4080 |
| 1988 | 1178 |
| 1989 | 1445 |
| 1990 | 2597 |
| 1991 | 3235 |
| 1992 | 1764 |
| 1993 | 1481 |
| 1994 | 1857 |
| 2002 | 1649 |
| 2019 | 2789 |

- **Gumbel Distribution Method Showing Prediction Stream flow (E.J.Gumbel-1935-54):**



- **Range of Operation of Maithon Reservoir:-**

| Year | Reservoir level (meter) | | Reservoir level (FEET) | |
|---|---|---|---|---|
| | Maximum (m) | Minimum (m) | Maximum (FT) | Minimum (FT) |
| 1955 | ------ | ------ | …….. | …… |
| 1956 | 141.3 | 123.3 | 463.7 | 404.5 |
| 1957 | 145.7 | 133.8 | 478.1 | 438.9 |
| 1958 | 150.0 | 137.9 | 492.2 | 452.3 |
| 1959 | 151.7 | 133.3 | 497.8 | 438.9 |
| 1960 | 148.5 | 131.1 | 487.2 | 430.3 |
| 1961 | 150.9 | 133.7 | 495.1 | 438.7 |
| 1962 | 146.7 | 135.2 | 481.4 | 443.7 |
| 1963 | 150.4 | 140.0 | 493.4 | 459.2 |
| 1964 | 146.39 | 136.0 | 480.3 | 446.3 |
| 1965 | 146.42 | 135.2 | 480.4 | 443.7 |
| 1966 | 141.5 | 135.7 | 464.4 | 445.2 |
| 1967 | 148.2 | 139.9 | 486.4 | 458.9 |
| 1968 | 149.6 | 140.0 | 490.7 | 459.2 |
| 1969 | 147.3 | 137.3 | 485.0 | 450.5 |
| 1970 | 150.3 | 138.8 | 493.0 | 455.3 |
| 1971 | 150.2 | 138.4 | 492.7 | 454.2 |
| 1972 | 148.0 | 133.0 | 485.7 | 436.3 |
| 1973 | 150.5 | 132.8 | 493.9 | 435.7 |
| 1974 | 147.5 | 134.2 | 484.0 | 440.2 |
| 1975 | 148.6 | 134.2 | 487.7 | 440.2 |

| Year | Reservoir level (meter) | | Reservoir level (FEET) | |
|---|---|---|---|---|
| | Maximum (m) | Minimum (m) | Maximum (FT) | Minimum (FT) |
| 1976 | 148.7 | 133.1 | 487.9 | 436.8 |
| 1977 | 148.8 | 135.4 | 488.3 | 444.3 |
| 1978 | 149.9 | 133.68 | 491.9 | 438.6 |
| 1979 | 148.1 | 133.6 | 486 | 438.2 |
| 1980 | 149.7 | 133.9 | 491.2 | 439.3 |
| 1981 | 144.9 | 134.1 | 475.4 | 440.1 |
| 1982 | 142.1 | 134.3 | 466.3 | 440.6 |
| 1983 | 148.3 | 133.6 | 486.6 | 438.3 |
| 1984 | 149.2 | 135.2 | 489.4 | 443.5 |
| 1985 | 148.8 | 133.7 | 488.3 | 438.8 |
| 1986 | 148.8 | 134.4 | 488.2 | 440.9 |
| 1987 | 149.8 | 135.3 | 491.3 | 443.8 |
| 1988 | 147.74 | 136.35 | 484.7 | 447.34 |
| 1989 | 148.82 | 134.74 | 487.26 | 442.05 |
| 1990 | 150.04 | 135.77 | 482.25 | 445.43 |
| 1991 | 149.79 | 135.81 | 491.43 | 445.57 |
| 1992 | 146.52 | 135.73 | 480.7 | 445.3 |
| 1993 | 148.73 | 136.68 | 487.95 | 448.42 |
| 1994 | 150.23 | 137.18 | 492.87 | 450.06 |
| 1995 | 149.69 | 134.97 | 491.1 | 442.81 |
| 1996 | 147.51 | 136.52 | 483.95 | 447.9 |
| 1997 | 148.38 | 137.6 | 486.81 | 451.44 |
| 1998 | 149.88 | 136.84 | 491.73 | 448.95 |
| 1999 | 149.74 | 138.02 | 491.27 | 452.82 |
| 2000 | 151.06 | 135.5 | 495.6 | 444.55 |
| 2001 | 148.95 | 135.64 | 488.68 | 447.6 |
| 2002 | 149.56 | 137.17 | 490.68 | 450.02 |
| 2019 | 145.82 | 137.34 | 478.41 | 450.60 |

## CAPACITY OF MAITHON RESERVOIR FOR DIFFERENT YEAR:-

Capacity of Maithon Reservoir (Acre ft) was computed up to E.l. 495 ft. (150.9m). The Below table shows reservoir capacity at different surveys at 10 feet (3m) depth interval as here under:-

| CAPACITY OF MAITHON RESERVOIR FOR DIFFERENT YEAR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| El. Feet | El. Meter | 1955 (Acre ft) | 1963 (Acre ft) | 1965 (Acre ft) | 1971 (Acre ft) | 1979 (Acre ft) | 1987 (Acre ft) | 1994 (Acre ft) | 2002 (Acre ft) | 2019 (Acre ft) |
| 350 | 106.7 | 81 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 360 | 109.8 | 1164 | 0 | 42 | 11 | 0 | 0 | 0 | 0 | 0 |
| 370 | 112.8 | 5446 | 1529 | 1694 | 832 | 517 | 166 | 0 | 0 | 0 |
| 380 | 115.9 | 13438 | 7289 | 7414 | 5559 | 3963 | 3248 | 2422 | 2230 | 594.00 |
| 390 | 118.9 | 25065 | 15435 | 15540 | 12972 | 10834 | 7940 | 6840 | 6510 | 3993.00 |
| 400 | 122.0 | 41161 | 29027 | 27849 | 25251 | 21440 | 16486 | 14040 | 13230 | 10809.12 |
| 410 | 125.0 | 63719 | 47925 | 45867 | 43169 | 37175 | 29788 | 25200 | 23930 | 21270.47 |
| 420 | 128.0 | 94582 | 74584 | 72463 | 69018 | 60264 | 49343 | 41100 | 39180 | 36928.43 |
| 430 | 131.1 | 137630 | 113114 | 109400 | 105536 | 91635 | 76594 | 62590 | 60920 | 58764.77 |
| 435 | 132.6 | 167430 | 140365 | 135547 | 130782 | 112455 | 95099 | 76920 | 75550 | 72805.99 |
| 440 | 134.1 | 197229 | 167616 | 161693 | 156028 | 136700 | 116858 | 93650 | 92700 | 88533.71 |
| 450 | 137.2 | 274372 | 238673 | 231334 | 221196 | 196251 | 172784 | 140110 | 136970 | 136806.11 |
| 460 | 140.2 | 373744 | 330806 | 321618 | 307726 | 278753 | 250879 | 219890 | 210590 | 204473.35 |
| 470 | 143.3 | 500290 | 450455 | 440945 | 423036 | 390555 | 355744 | 324740 | 307160 | 299277.38 |
| 480 | 146.3 | 659737 | 605687 | 596503 | 572254 | 537707 | 493577 | 458740 | 433410 | 421127.41 |
| 490 | 149.4 | 855907 | 801505 | 793453 | 765015 | 728555 | 682306 | 641620 | 598700 | 581684.88 |
| 495 | 150.9 | 969503 | 918322 | 909673 | 881000 | 844072 | 795242 | 755235 | 703980 | 685078.27 |

## Capacity Table –Maithon Reservoir, 2019 (Pre-Monsoon):-

The Elevation with capacity table of Maithon Reservoir 2019 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 in Feet | Elevation in Meter | Capacity in Acre Feet | Capacity in MCM |
|---|---|---|---|
| 372 | 113.4 | 0.02 | 0.00 |
| 373 | 113.7 | 0.06 | 0.00 |
| 374 | 114.0 | 0.15 | 0.00 |
| 375 | 114.3 | 6.41 | 0.01 |
| 376 | 114.6 | 34.40 | 0.04 |
| 377 | 114.9 | 124.41 | 0.15 |
| 378 | 115.2 | 154.04 | 0.19 |
| 379 | 115.5 | 418.47 | 0.52 |
| 380 | 115.8 | 594.00 | 0.73 |
| 381 | 116.1 | 796.45 | 0.98 |
| 382 | 116.4 | 1023.86 | 1.26 |
| 383 | 116.7 | 1276.24 | 1.57 |
| 384 | 117.0 | 1570.43 | 1.94 |
| 385 | 117.3 | 1898.60 | 2.34 |
| 386 | 117.7 | 2252.34 | 2.78 |
| 387 | 118.0 | 2639.83 | 3.26 |
| 388 | 118.3 | 3067.29 | 3.78 |
| 389 | 118.6 | 3518.35 | 4.34 |
| 390 | 118.9 | 3993.00 | 4.93 |
| 391 | 119.2 | 4496.86 | 5.55 |
| 392 | 119.5 | 5035.54 | 6.21 |

| Elevation in Feet | Elevation in Meter | Capacity in Acre Feet | Capacity in MCM |
|---|---|---|---|
| 393 | 119.8 | 5609.04 | 6.92 |
| 394 | 120.1 | 6239.13 | 7.70 |
| 395 | 120.4 | 6910.54 | 8.52 |
| 396 | 120.7 | 7612.41 | 9.39 |
| 397 | 121.0 | 8354.52 | 10.31 |
| 398 | 121.3 | 9144.46 | 11.28 |
| 399 | 121.6 | 9962.66 | 12.29 |
| 400 | 121.9 | 10809.12 | 13.33 |
| 401 | 122.2 | 11682.95 | 14.41 |
| 402 | 122.5 | 12583.23 | 15.52 |
| 403 | 122.8 | 13827.72 | 17.06 |
| 404 | 123.1 | 14483.59 | 17.87 |
| 405 | 123.4 | 15502.15 | 19.12 |
| 406 | 123.7 | 16555.44 | 20.42 |
| 407 | 124.1 | 17655.89 | 21.78 |
| 408 | 124.4 | 18820.97 | 23.22 |
| 409 | 124.7 | 20025.83 | 24.70 |
| 410 | 125.0 | 21270.47 | 26.24 |
| 411 | 125.3 | 22558.65 | 27.83 |
| 412 | 125.6 | 23894.14 | 29.47 |
| 413 | 125.9 | 25753.63 | 31.77 |

| Elevation in Feet | Elevation in Meter | Capacity in Acre Feet | Capacity in MCM |
|---|---|---|---|
| 414 | 126.2 | 26740.17 | 32.98 |
| 415 | 126.5 | 28272.13 | 34.87 |
| 416 | 126.8 | 29856.21 | 36.83 |
| 417 | 127.1 | 31510.75 | 38.87 |
| 418 | 127.4 | 33259.66 | 41.03 |
| 419 | 127.7 | 35066.32 | 43.25 |
| 420 | 128.0 | 36928.43 | 45.55 |
| 421 | 128.3 | 38844.15 | 47.91 |
| 422 | 128.6 | 40813.94 | 50.34 |
| 423 | 128.9 | 43524.40 | 53.69 |
| 424 | 129.2 | 44921.93 | 55.41 |
| 425 | 129.5 | 47086.75 | 58.08 |
| 426 | 129.8 | 50877.54 | 62.76 |
| 427 | 130.1 | 51659.31 | 63.72 |
| 428 | 130.5 | 54013.90 | 66.63 |
| 429 | 130.8 | 56382.39 | 69.55 |
| 430 | 131.1 | 58764.77 | 72.49 |
| 431 | 131.4 | 61191.80 | 75.48 |
| 432 | 131.7 | 63694.22 | 78.57 |
| 433 | 132.0 | 67148.03 | 82.83 |
| 434 | 132.3 | 68950.29 | 85.05 |
| 435 | 132.6 | 72805.99 | 89.80 |
| 436 | 132.9 | 76996.58 | 94.97 |
| 437 | 133.2 | 78092.50 | 96.33 |
| 438 | 133.5 | 81457.33 | 100.48 |
| 439 | 133.8 | 84937.74 | 104.77 |
| 440 | 134.1 | 88533.71 | 109.20 |
| 441 | 134.4 | 96153.67 | 118.60 |
| 442 | 134.7 | 100197.96 | 123.59 |
| 443 | 135.0 | 104381.32 | 128.75 |
| 444 | 135.3 | 108648.01 | 134.02 |
| 445 | 135.6 | 112993.75 | 139.38 |

| Elevation in Feet | Elevation in Meter | Capacity in Acre Feet | Capacity in MCM |
|---|---|---|---|
| 446 | 135.9 | 117423.58 | 144.84 |
| 447 | 136.2 | 122002.99 | 150.49 |
| 448 | 136.6 | 126752.15 | 156.35 |
| 449 | 136.9 | 131671.04 | 162.41 |
| 450 | 137.2 | 136806.11 | 168.75 |
| 451 | 137.5 | 142203.78 | 175.41 |
| 452 | 137.8 | 147864.05 | 182.39 |
| 453 | 138.1 | 153792.21 | 189.70 |
| 454 | 138.4 | 160005.45 | 197.36 |
| 455 | 138.7 | 166505.09 | 205.38 |
| 456 | 139.0 | 173298.72 | 213.76 |
| 457 | 139.3 | 180484.84 | 222.62 |
| 458 | 139.6 | 188093.78 | 232.01 |
| 459 | 139.9 | 196125.55 | 241.92 |
| 460 | 140.2 | 204473.35 | 252.21 |
| 461 | 140.5 | 213030.41 | 262.77 |
| 462 | 140.8 | 224765.35 | 277.24 |
| 463 | 141.1 | 230770.11 | 284.65 |
| 464 | 141.4 | 239943.30 | 295.97 |
| 465 | 141.7 | 249315.77 | 307.53 |
| 466 | 142.0 | 258887.91 | 319.33 |
| 467 | 142.3 | 268664.83 | 331.39 |
| 468 | 142.6 | 278648.10 | 343.71 |
| 469 | 143.0 | 288837.74 | 356.28 |
| 470 | 143.3 | 299277.38 | 369.15 |
| 471 | 143.6 | 310010.68 | 382.39 |
| 472 | 143.9 | 324778.54 | 400.61 |
| 473 | 144.2 | 332373.43 | 409.98 |
| 474 | 144.5 | 344067.45 | 424.40 |
| 475 | 144.8 | 356123.49 | 439.27 |
| 476 | 145.1 | 368536.97 | 454.58 |
| 477 | 145.4 | 381248.50 | 470.26 |

| Elevation in Feet | Elevation in Meter | Capacity in Acre Feet | Capacity in MCM |
|---|---|---|---|
| 478 | 145.7 | 394239.80 | 486.29 |
| 479 | 146.0 | 407510.87 | 502.66 |
| 480 | 146.3 | 421127.41 | 519.45 |
| 481 | 146.6 | 435155.12 | 536.76 |
| 482 | 146.9 | 454498.31 | 560.62 |
| 483 | 147.2 | 464460.59 | 572.90 |
| 484 | 147.5 | 479808.82 | 591.84 |
| 485 | 147.8 | 506468.70 | 624.72 |
| 486 | 148.1 | 511960.27 | 631.49 |

| Elevation in Feet | Elevation in Meter | Capacity in Acre Feet | Capacity in MCM |
|---|---|---|---|
| 487 | 148.4 | 528730.87 | 652.18 |
| 488 | 148.7 | 545945.31 | 673.41 |
| 489 | 149.0 | 563603.59 | 695.19 |
| 490 | 149.4 | 581684.88 | 717.50 |
| 491 | 149.7 | 600168.35 | 740.30 |
| 492 | 150.0 | 625438.59 | 771.47 |
| 493 | 150.3 | 638350.10 | 787.39 |
| 494 | 150.6 | 658083.53 | 811.73 |
| 495 | 150.9 | 685078.27 | 845.03 |

# ESTIMATION OF SEDIMENTATION IN DIFFERENT ZONES OF RESERVOIR (iii)

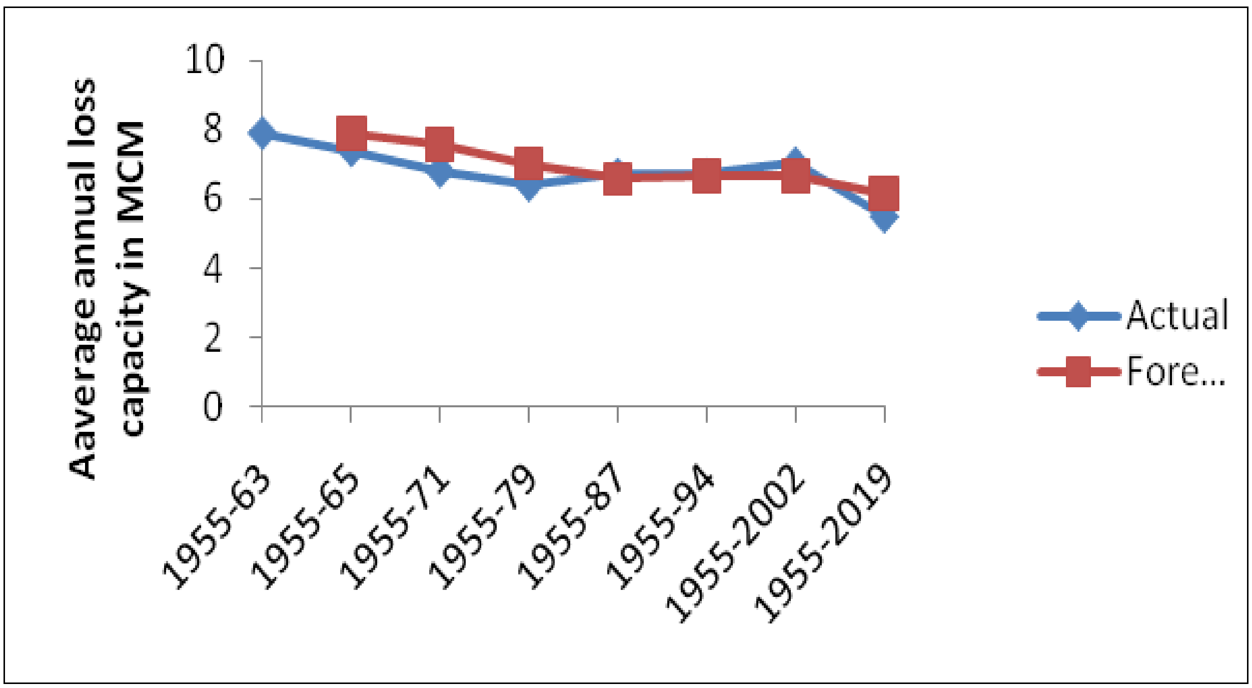
This section has been analyzed loss of storage capacity, rate of sedimentation in each vertical zone separately viz. dead storage, live storage and flood storage etc.

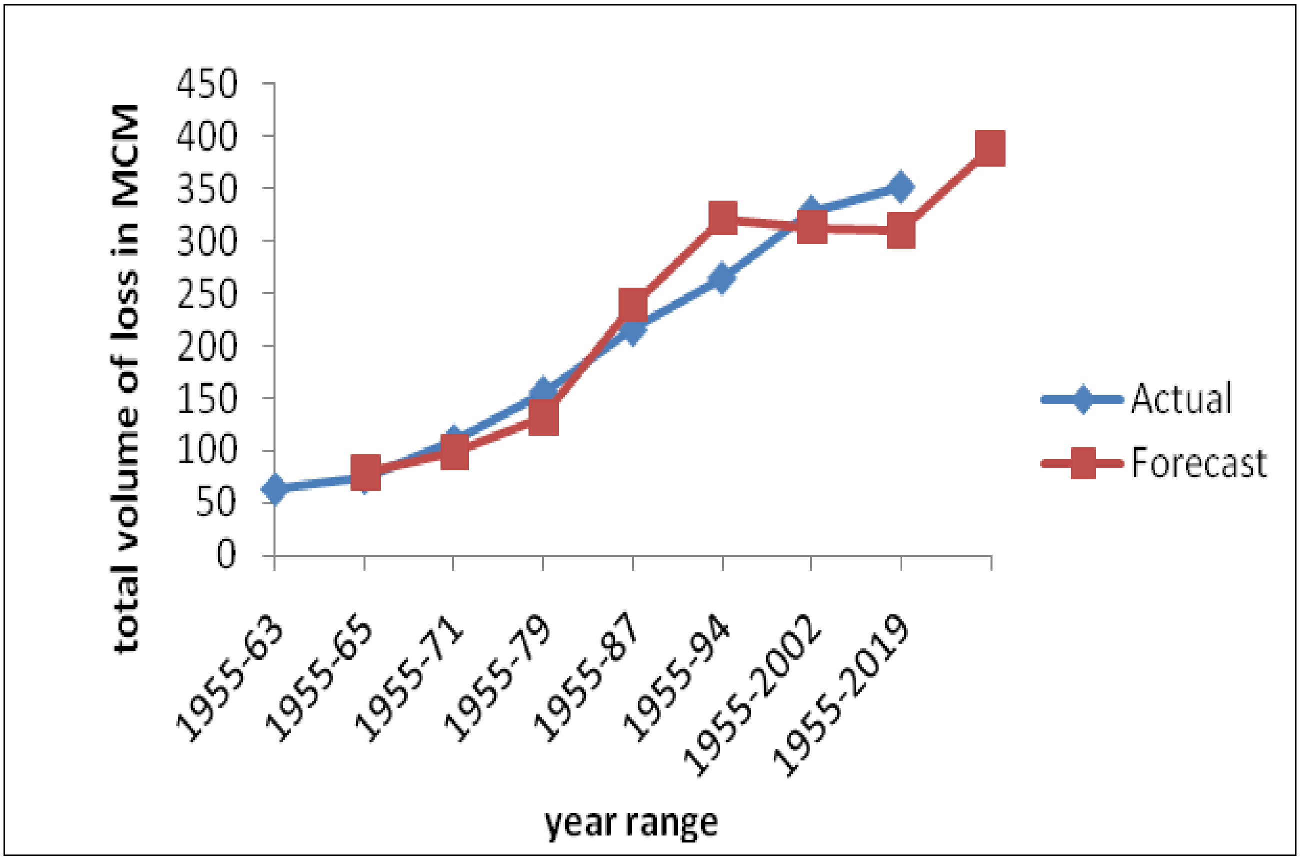
## 13.3 Estimation of Sedimentation in different zones of Reservoir:-

### 13.3.1 Loss of Storage Capacity:-

| Loss of Storage Capacity in Maithon Reservoir | | | | | |
|---|---|---|---|---|---|
| Period | No. of years | Total volume of Loss of Capacity | | Average Annual loss of Capacity | |
| | | Acre Feet | $10^6$ $m^3$ | Acre Feet | $10^6$ $m^3$ |
| 1955-63 | 8 | 51,181 | 63 | 6398 | 7.9 |
| 1955-65 | 10 | 59,830 | 74 | 5983 | 7.4 |
| 1955-71 | 16 | 88,503 | 109 | 5531 | 6.8 |
| 1955-79 | 24 | 1,25,431 | 155 | 5226 | 6.4 |
| 1955-87 | 32 | 1,74,261 | 215 | 5446 | 6.7 |
| 1955-94 | 39 | 2,14,268 | 264 | 5494 | 6.7 |
| 1955-2002 | 47 | 2,65,523 | 327 | 5695 | 7.02 |
| 1955-2019 | 64 | 2,84,423 | 351 | 4444 | 5.48 |

Table Shows total and average annual loss of capacity and percent loss of capacity at different zones.




450
400
350
300
250
200
150
100
50
0
total volume of loss in MCM
1955-63
1955-65
1955-71
1955-79
1955-87
1955-94
1955-2002
1955-2019
year range
Actual
Forecast

### 13.3.2 Sediment Deposition Rate in Maithon Reservoir:-

Total volume of sediment deposit up to August, 2019 computed by contouring method comes to about 3255417.3 Acre feet (421.86 Million $M^3$). The Average annual rate of sediment deposition per unit catchment area comes to 2.72 acre feet/square mile/year (1402 $M^3$/Sq.km/year). The above table shows a comparative review of sediment deposition rate observed from the different surveys.

| Between Years | No. of years | Volume of Deposit | | Sediment Deposition Rate | |
|---|---|---|---|---|---|
| | | Acre feet | $MM^3$ | Aft./Sq. mile/year | $M^3$ /Sq/km per year |
| 1 | 2 | 3 | 4 | 5 | 6 |
| 1955-63 | 8 | 51181 | 63 | 3.2 | 1524 |
| 1955-65 | 10 | 59830 | 74 | 3 | 1429 |
| 1955-71 | 16 | 88503 | 109 | 2.8 | 1333 |
| 1955-79 | 24 | 125431 | 155 | 2.6 | 1238 |
| 1955-87 | 32 | 174261 | 215 | 2.71 | 1290 |
| 1955-94 | 39 | 214268 | 264.24 | 2.74 | 1304 |
| 1955-2002 | 47 | 265523 | 327.66 | 2.75 | 1305 |
| 1955-2019 | 64 | 3255417.3 | 421.86 | 2.72 | 1402 |

### 13.3.3 Estimation of Sedimentation in different zones of Reservoir:-

The Below table shows sedimentation in three different zones viz. Flood zone, live zone and Dead zone:-

| EL IN M. | CAP IN MCM | | CAP-LOSS 2002-2019 |
|---|---|---|---|
| | 2002 | 2019 | |
| 150.9 | 868.35 | 845.03 | 23.32 |
| 150.0 | 787.80 | 771.47 | 16.33 |
| 147.0 | 571.35 | 560.62 | 10.73 |
| 146.3 | 534.60 | 519.45 | 15.15 |
| 146.0 | 517.38 | 502.66 | 14.72 |
| 143.0 | 365.69 | 356.28 | 9.41 |
| 139.0 | 219.09 | 210.92 | 8.17 |
| 136.0 | 145.25 | 143.00 | 2.25 |
| 132.6 | 93.19 | 89.80 | 3.39 |
| 132.0 | 85.53 | 82.83 | 2.70 |
| 129.0 | 55.49 | 53.69 | 1.80 |
| 128.0 | 48.33 | 45.55 | 2.78 |
| 125.0 | 29.52 | 26.24 | 3.28 |
| 122.0 | 16.32 | 13.33 | 2.99 |
| 121.0 | 13.51 | 9.99 | 3.52 |
| 118.0 | 6.18 | 3.09 | 3.09 |
| 113.0 | 0.00 | 0.00 | 0.00 |

| LOSS OF CAP IN FLOOD ZONE | | | |
|---|---|---|---|
| EL | 150.9 | 146.3 | LIVE CAP |
| YEAR | CAP IN MCM | | |
| 2002 | 868.35 | 534.60 | 333.75 |
| 2019 | 845.03 | 519.45 | 325.58 |
| LOSS OF CAP IN FLOOD ZONE | | | 8.17 |

| LOSS OF CAP IN LIVE ZONE | | | |
|---|---|---|---|
| EL | 146.3 | 132.6 | LIVE CAP |
| YEAR | CAP IN MCM | | |
| 2002 | 534.60 | 93.19 | 441.41 |
| 2019 | 519.45 | 89.80 | 429.65 |
| LOSS OF CAP IN LIVE ZONE | | | 11.76 |

| LOSS OF CAP IN DEAD ZONE | | | |
|---|---|---|---|
| EL | 132.6 | 113 | LIVE CAP |
| YEAR | CAP IN MCM | | |
| 2002 | 93.19 | 0.00 | 93.19 |
| 2019 | 89.80 | 0.00 | 89.80 |
| LOSS OF CAP IN DEAD ZONE | | | 3.39 |

**Total Loss of Capacity- 23.32 MCM (18905 Acre Feet)**

# 13.3.4 Loss of Reservoir Curve:-

### 13.3.5 Distribution of Sediment deposit in different reaches of Maithon Reservoir:-

The below table shows the amount of sediment deposition in Maithon Reservoir in different reaches of upstream of Dam.

A forecast formula is a mathematical relationship that can be used to automatically calculate forecasts of demand. This is done using demand history data.

**Description**

Forecast formulas are used to calculate fresh base forecast from actual demand adjusted for seasonal and period length variations. A formula is specified for each forecast method. The method also contains specified parameters and limits which regulate the calculation performed using the formula.

**Formulas**

There are four forecast formulas, as follows:

**Moving average**

This forecast formula calculates the base forecast for the next period as the average of historic base demand for a specified number of periods. This is denoted in the following equation:

F(i + 1) = (D(i) + D(i - 1) + .... + D(i - (n - 1))) / n

The number of periods used determines how quickly the averaging will react to changes in actual trends and how sensitive it will be to random variations. The more periods included will make the calculation method more stable from random variations, but it will also react more slowly to changes resulting from real trends.

**Forecast Formulas:Two-period weighted average**

This forecast formula weighs the average demand from the latest quarter (of periods included in the forecast) with the average demand for all historic periods. The weight factor is the smoothing constant for exponential smoothing, (, and 1 - (, respectively. This is denoted in the following equation:

F(i + 1) = ((i) * M + (1 - ((i)) * L

**Exponential smoothing**

This forecast formula weighs latest base demand value with the smoothing constant (, while the previous base forecast value is weighted with 1 - (. This is denoted in the following equation:

F(i + 1) = ((i) * D(i) + (1 - ((i)) * F(i)

The value of smoothing constant (determines how quickly the forecast will react to changes in actual trends and how sensitive it will be to random variations. The lower the value, the more stable the calculation is from random variations, but it will also react more slowly to changes resulting from real trends. Smoothing constant ( must be between 0 and 1.

**Forecast Formulas: Adaptive exponential smoothing**

This forecast formula is similar to basic exponential smoothing in that the latest base demand value is weighted with smoothing constant (, while the previous base forecast value is weighted with 1 - (. However, in adaptive exponential smoothing, the smoothing constant is recalculated every time a new forecast is made. This is denoted in the following equation:

F(i + 1) = ((i) * D(i) + (1 - ((i)) * F(i)

The smoothing constant is recalculated using the following equation:

((i) = ((min.) + ((max.) * (ABS (ME (i)) / MAD (i))

This forecast formula uses (values that are adjusted for the current systematic forecast error. A larger mean forecast error results in a higher (value. This results in a quicker correction to the forecast towards reflecting actual demand.

**Description**

The examples below describe using each of the formulas based on the following data.

| | Aug. | Sep. | Oct. | Nov. |
|---|---|---|---|---|
| Base demand | 120 | 145 | 138 | 129 |
| Base forecast for Nov. | 136 | | | |
| (-factor used | 0.3 | | | |
| ((min.) | 0.2 | | | |
| ((Max.) | 0.5 | | | |
| MAD(Nov.) | 10 | | | |
| ME(Nov.) | -2 | | | |

The following forecast values will be calculated for December using the four methods as listed:

**Moving average**

F (Dec.) = (D (Aug.) + D (Sep.) + D (Oct.) + D (Nov.)) / 4 = (120 + 145 + 138 + 129) / 4 = 133

**Two-period weighted average**

F (Dec.) = 0.3 * 129 / 1+ 0.7 * (120 + 145 + 138 + 129) / 4 = 0.3 * 129 + 0.7 * 133 = 131.8

**Exponential smoothing**

F (Dec.) = 0.3 * D (Nov.) + 0.7 * F (Nov.) = 0.3 * 129 + 0.7 * 136 = 133.9

**Adaptive exponential smoothing**

((Nov.) = ((min.) + ((max.) * (ABS (ME (i)) / MAD (i)) = 0.2 + 0.5 * ABS (-2) / 10 = 0.2 + 0.5 * 0.2 = 0.21

F(Dec.) = ((Nov.) * D(Nov.) + (1 - ((Nov.)) * F(Nov.) = 0.21 * 129 + 0.79 * 136 = 134.5

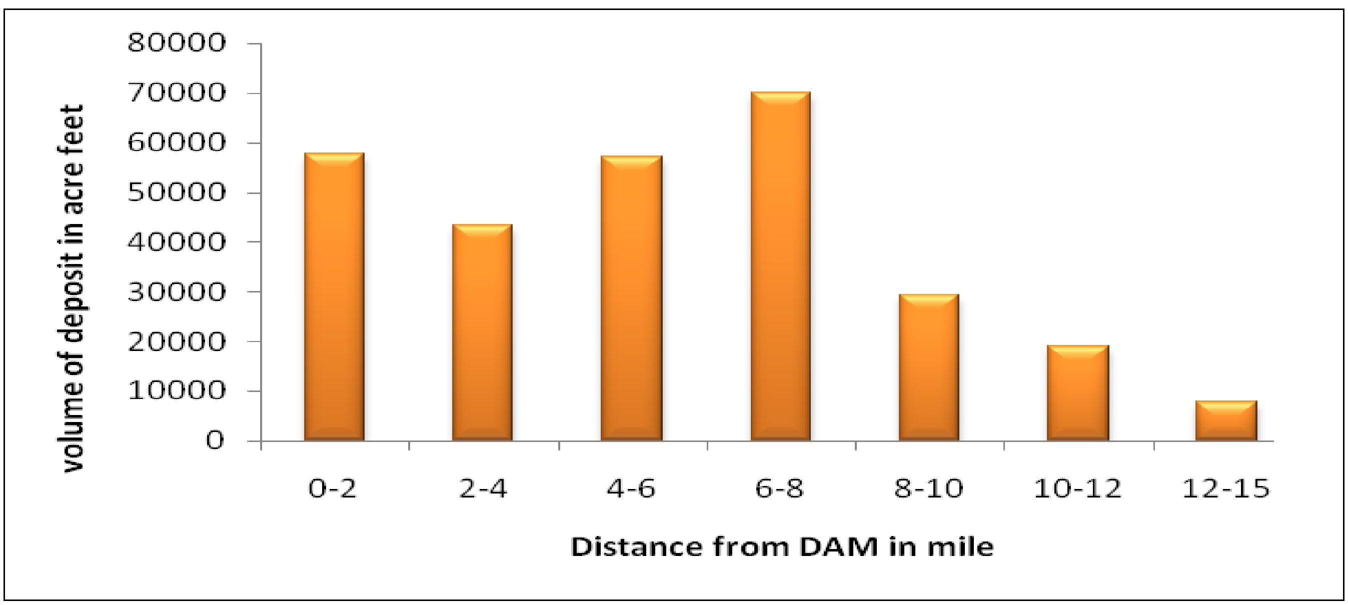
You can estimate and predict the value of Y using a multiple regression equation. With multiple regression analysis, the population regression equation may contain any number of independent variables, such as

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki} + \varepsilon_i$$

In this case, there are k independent variables, indexed from 1 to k.

- **Distribution of Sediment Deposit in Different Reaches:-**

| DISTRIBUTION OF SEDIMENT DEPOSIT IN DIFFERENT REACHES OF MAITHON RESERVOIR | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| REACH MILES | PERCENT OF TOTAL VOLUME OF DEPOSIT | | | | | | | | REACH (KM U/S) |
| U/S | 1963 | 1965 | 1971 | 1979 | 1987 | 1994 | 2002 | 2019 | |
| 0-2 | 11.4 | 6.5 | 4.8 | 8 | 13 | 22 | 22 | 20.30 | (0-3.2) |
| 2-4 | 21.8 | 21.5 | 15.1 | 15 | 14 | 15.89 | 15 | 15.25 | (3.2-6.4) |
| 4-6 | 18.7 | 17.8 | 15.7 | 22 | 22 | 17.15 | 18 | 20.11 | (6.4-9.6) |
| 6-8 | 15.2 | 20.5 | 26.1 | 23 | 25 | 23.9 | 27 | 24.60 | (9.6-12.8) |
| 8-10 | 15.3 | 15.6 | 17.4 | 15 | 13 | 11.49 | 10 | 10.34 | (12.8-16.0) |
| 10-12 | 7.7 | 8.2 | 12 | 10 | 8 | 5.79 | 6 | 6.70 | (16-19.2) |
| 12-15 | 9.9 | 9.9 | 8.9 | 7 | 5 | 3.79 | 2 | 2.70 | (19.2-24.0) |
| Total Vol | 51183 | 59830 | 88503 | 125431 | 174261 | 214268 | 265528 | 284422 | Acre Feet |
| | 63 | 74 | 109 | 155 | 215 | 264 | 328 | 351 | MCM |



13.3.6 Depth wise Location of Deposit in percentage of Maithon Reservoir:-

The Below table shows the depth wise sediment distribution for Maithon Reservoir. The below table has been computed with reference to **para no – 13.3.5**

| DEPTH -WISE LOCATION OF DEPOSIT IN MAITHON RESERVOIR | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **BET ELE IN FT/M** | 349-360 106.37-109.73 | 360-370 109.73-112.77 | 370-380 112.77-115.82 | 380-390 115.82-118.88 | 390-400 118.88-121.92 | 400-410 121.92-124.97 | 410-420 124.97-128.01 | 420-130 128.01-131.06 | 430-440 131.06-134.11 | 440-450 134.11-137.16 | 450-460 137.16-140.21 | 460-470 140.21-143.25 | 470-500 143.25-152.40 |
| **DEPTH IN FT/M** | 0-11 0-3.34 | 11.21 3.34-6.39 | 21-31 6.39-9.44 | 31-41 9.44-12.49 | 41-51 12.49-15.54 | 51-61 | 61-71 18.59-21.64 | 71-81 21.64-24.69 | 81-91 24.69-27.74 | 91-101 27.74-30.79 | 101-111 30.79-33.84 | 111-121 33.84-36.39 | 121-151 36.89-46.03 |
| **1963** | 2 | 5 | 4 | 7 | 5 | 7 | 8 | 9 | 10 | 12 | 14 | 14 | 3 |
| **1965** | 2 | 4 | 4 | 6 | 6 | 8 | 7 | 10 | 4 | 21 | 15 | 12 | 1 |
| **1971** | 1 | 4 | 4 | 5 | 4 | 5 | 6 | 7 | 11 | 13 | 15 | 12 | 13 |
| **1979** | 1 | 3 | 3 | 4 | 5 | 5 | 6 | 9 | 12 | 14 | 14 | 12 | 12 |
| **1987** | 1 | 2 | 3 | 4 | 4 | 5 | 7 | 9 | 11 | 12 | 12 | 13 | 17 |
| **1994** | 1 | 2 | 3 | 3 | 4 | 5 | 7 | 10 | 14 | 14 | 9 | 10 | 18 |
| **2002** | 1 | 2 | 2 | 3 | 4 | 4 | 6 | 9 | 10 | 12 | 9 | 11 | 27 |
| **2019** | 0 | 0 | 1 | 1 | 2 | 2 | 5 | 7 | 12 | 14 | 11 | 19 | 22 |

Table 6-Depth wise Sedimentation in different year

# ANALYSIS OF BED MATERIAL SAMPLES (iv)

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

13.4 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.

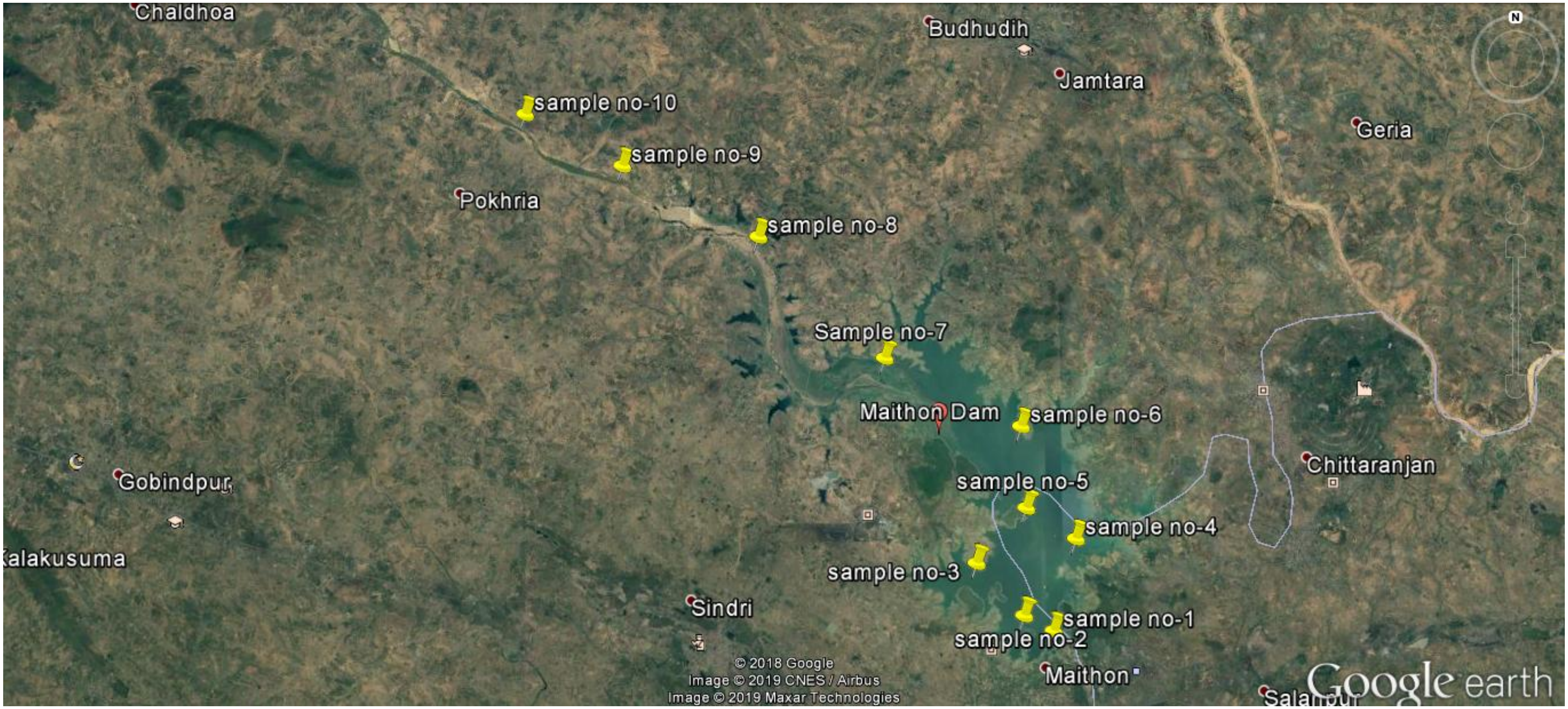
## 2.0 Natural Moisture Content (NMC) (As per IS: 2720(Part-1)-1983)

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.

## 3.0Specific 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.

13.4.1 Soil Sample Positions:-



### 13.4.2 Sediment Size, Density, Specific Gravity and Moisture Content:-

| SITE: MAITHON DAM (DVC) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| TEST RESULTS | | | | | | | | | | |
| Sl. No. | Sample No. | Description | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Moisture Content (%) | Specific Gravity | Uniformity of soil |
| 1 | 1 | Brownish grey clayey silt | 0.00 | 3.16 | 60.09 | 36.75 | 69.00 | 2.52 | Non-uniform |
| 2 | 2 | Brownish grey clayey silt | 0.00 | 2.30 | 62.87 | 34.83 | 47.24 | 2.53 | Non-uniform |
| 3 | 3 | Brownish grey clayey silt | 0.00 | 0.60 | 66.80 | 32.60 | 63.51 | 2.67 | Non-uniform |
| 4 | 4 | Brownish grey clayey silt | 0.00 | 0.08 | 68.49 | 31.43 | 65.01 | 2.51 | Non-uniform |
| 5 | 5 | Greyish Sandy clay | 0.00 | 55.88 | 44.12 | | 75.01 | 2.81 | Non-uniform |
| 6 | 6 | Brownish greyish Silty Sand | 0.00 | 50.99 | 49.01 | | 33.23 | 2.77 | Non-uniform |
| 7 | 7 | Grey silty sand with gravel | 17.80 | 63.78 | 18.42 | | 14.20 | 2.71 | Uniform |
| 8 | 8 | Brownish grey sandy clayey silt | 1.17 | 17.51 | 57.86 | 23.46 | 25.31 | 2.61 | Non-uniform |
| 9 | 9 | Brownish grey clayey silt | 0.00 | 0.52 | 67.84 | 31.63 | 29.29 | 2.53 | Non-uniform |
| 10 | 10 | Brownish grey clayey silt with low traces of sand | 0.00 | 9.20 | 58.27 | 32.53 | 65.50 | 2.56 | Non-uniform |

## 13.4.3 Bulk Density of the samples:-

SITE: MAITHON DAM

Bulk Density

Sample-1

| | | Reservoir condition: | B for Clay | B for Silt | B for Sand | Avg B |
|---|---|---|---|---|---|---|
| Sand (%) | 3.16 | Cont. Submerged | 256 | 91 | 0 | 1.49 |
| Silt (%) | 60.09 | Periodic drwadown | 135 | 29 | 0 | 0.67 |
| Clay (%) | 36.75 | Resvr. normally empty | 0 | 0 | 0 | 0.00 |

| | Miller's Method | | | | | | Lane's Method | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reservoir condition:** | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ |
| Cont. Submerged | 862.23 | 862.48 | 862.65 | 862.78 | 862.88 | 862.88 | 862.68 | 862.94 | 863.12 | 863.27 | 863.39 |
| Periodic drwadown | 927.53 | 927.65 | 927.72 | 927.78 | 927.83 | 927.83 | 927.74 | 927.85 | 927.94 | 928.00 | 928.06 |
| Resvr. normally empty | 962.94 | 962.94 | 962.94 | 962.94 | 962.94 | 962.94 | 962.94 | 962.94 | 962.94 | 962.94 | 962.94 |

Sample-2

| | | Reservoir condition: | B for Clay | B for Silt | B for Sand | Avg B |
|---|---|---|---|---|---|---|
| Sand (%) | 2.3 | Cont. Submerged | 256 | 91 | 0 | 1.46 |
| Silt (%) | 62.87 | Periodic drwadown | 135 | 29 | 0 | 0.65 |
| Clay (%) | 34.83 | Resvr. normally empty | 0 | 0 | 0 | 0.00 |

| | Miller's Method | | | | | | Lane's Method | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reservoir condition:** | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ |
| Cont. Submerged | 875.49 | 875.73 | 875.90 | 876.03 | 876.13 | 876.13 | 875.93 | 876.19 | 876.37 | 876.51 | 876.63 |
| Periodic drwadown | 938.56 | 938.67 | 938.75 | 938.80 | 938.85 | 938.85 | 938.76 | 938.88 | 938.96 | 939.02 | 939.07 |
| Resvr. normally empty | 972.72 | 972.72 | 972.72 | 972.72 | 972.72 | 972.72 | 972.72 | 972.72 | 972.72 | 972.72 | 972.72 |

Sample-3

| | | Reservoir condition: | B for Clay | B for Silt | B for Sand | Avg B |
|---|---|---|---|---|---|---|
| Sand (%) | 0.6 | Cont. Submerged | 256 | 91 | 0 | 1.44 |
| Silt (%) | 66.8 | Periodic drwadown | 135 | 29 | 0 | 0.63 |
| Clay (%) | 32.6 | Resvr. normally empty | 0 | 0 | 0 | 0.00 |

**Miller's Method** **Lane's Method**

SITE: MAITHON DAM

Bulk Density

| Reservoir condition: | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cont. Submerged | 890.68 | 890.92 | 891.08 | 891.21 | 891.31 | 891.31 | 891.11 | 891.36 | 891.54 | 891.68 | 891.80 |
| Periodic drwadown | 951.31 | 951.41 | 951.48 | 951.54 | 951.58 | 951.58 | 951.50 | 951.61 | 951.69 | 951.75 | 951.80 |
| Resvr. normally empty | 984.07 | 984.07 | 984.07 | 984.07 | 984.07 | 984.07 | 984.07 | 984.07 | 984.07 | 984.07 | 984.07 |

Sample-4

| | | Reservoir condition: | B for Clay | B for Silt | B for Sand | Avg B |
|---|---|---|---|---|---|---|
| Sand (%) | 0.08 | Cont. Submerged | 256 | 91 | 0 | 1.43 |
| Silt (%) | 68.49 | Periodic drwadown | 135 | 29 | 0 | 0.62 |
| Clay (%) | 31.43 | Resvr. normally empty | 0 | 0 | 0 | 0.00 |

| | Miller's Method | | | | | | Lane's Method | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Reservoir condition: | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ |
| Cont. Submerged | 898.76 | 899.00 | 899.16 | 899.28 | 899.38 | 899.38 | 899.19 | 899.44 | 899.62 | 899.75 | 899.87 |
| Periodic drwadown | 958.03 | 958.13 | 958.20 | 958.26 | 958.30 | 958.30 | 958.22 | 958.33 | 958.40 | 958.46 | 958.51 |
| Resvr. normally empty | 990.02 | 990.02 | 990.02 | 990.02 | 990.02 | 990.02 | 990.02 | 990.02 | 990.02 | 990.02 | 990.02 |

Sample-5

| | | Reservoir condition: | B for Clay | B for Silt | B for Sand | Avg B |
|---|---|---|---|---|---|---|
| Sand (%) | 55.88 | Cont. Submerged | 256 | 91 | 0 | 0.40 |
| Silt (%) | 44.12 | Periodic drwadown | 135 | 29 | 0 | 0.13 |
| Clay (%) | 0 | Resvr. normally empty | 0 | 0 | 0 | 0.00 |

| | Miller's Method | | | | | | Lane's Method | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Reservoir condition: | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ |
| Cont. Submerged | 1136.76 | 1136.83 | 1136.88 | 1136.91 | 1136.94 | 1136.94 | 1136.88 | 1136.96 | 1137.01 | 1137.04 | 1137.08 |
| Periodic drwadown | 1145.59 | 1145.61 | 1145.62 | 1145.64 | 1145.64 | 1145.64 | 1145.63 | 1145.65 | 1145.67 | 1145.68 | 1145.69 |
| Resvr. normally empty | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 |

Sample-6

| | | Reservoir condition: | B for Clay | B for Silt | B for Sand | Avg B |
|---|---|---|---|---|---|---|
| Sand (%) | 50.99 | | | | | |

SITE: MAITHON DAM

Bulk Density

| | | | | | | |
|---|---|---|---|---|---|---|
| Silt (%) | 49.01 | Cont. Submerged | 256 | 91 | 0 | 0.45 |
| Clay (%) | 0 | Periodic drwadown | 135 | 29 | 0 | 0.14 |
| | | Resvr. normally empty | 0 | 0 | 0 | 0.00 |

| | Miller's Method | | | | | | Lane's Method | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reservoir condition:** | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ |
| Cont. Submerged | 1135.30 | 1135.37 | 1135.42 | 1135.46 | 1135.49 | 1135.49 | 1135.43 | 1135.51 | 1135.57 | 1135.61 | 1135.64 |
| Periodic drwadown | 1145.10 | 1145.12 | 1145.14 | 1145.15 | 1145.16 | 1145.16 | 1145.14 | 1145.17 | 1145.18 | 1145.20 | 1145.21 |
| Resvr. normally empty | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 |

Sample-7

| | | | | | | |
|---|---|---|---|---|---|---|
| Sand (%) | 81.58 | **Reservoir condition:** | B for Clay | B for Silt | B for Sand | Avg B |
| Silt (%) | 18.42 | Cont. Submerged | 256 | 91 | 0 | 0.17 |
| Clay (%) | 0 | Periodic drwadown | 135 | 29 | 0 | 0.05 |
| | | Resvr. normally empty | 0 | 0 | 0 | 0.00 |

| | Miller's Method | | | | | | Lane's Method | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reservoir condition:** | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ |
| Cont. Submerged | 1144.47 | 1144.50 | 1144.52 | 1144.54 | 1144.55 | 1144.55 | 1144.52 | 1144.55 | 1144.57 | 1144.59 | 1144.60 |
| Periodic drwadown | 1148.16 | 1148.17 | 1148.17 | 1148.18 | 1148.18 | 1148.18 | 1148.17 | 1148.18 | 1148.19 | 1148.20 | 1148.20 |
| Resvr. normally empty | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 | 1150.00 |

Sample-8

| | | | | | | |
|---|---|---|---|---|---|---|
| Sand (%) | 18.68 | **Reservoir condition:** | B for Clay | B for Silt | B for Sand | Avg B |
| Silt (%) | 57.86 | Cont. Submerged | 256 | 91 | 0 | 1.13 |
| Clay (%) | 23.46 | Periodic drwadown | 135 | 29 | 0 | 0.48 |
| | | Resvr. normally empty | 0 | 0 | 0 | 0.00 |

| | Miller's Method | | | | | | Lane's Method | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reservoir condition:** | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ |
| Cont. Submerged | 960.45 | 960.63 | 960.76 | 960.86 | 960.94 | 960.94 | 960.78 | 960.98 | 961.12 | 961.23 | 961.32 |
| Periodic drwadown | 1006.03 | 1006.12 | 1006.17 | 1006.21 | 1006.25 | 1006.25 | 1006.18 | 1006.27 | 1006.33 | 1006.37 | 1006.41 |
| Resvr. normally empty | 1030.59 | 1030.59 | 1030.59 | 1030.59 | 1030.59 | 1030.59 | 1030.59 | 1030.59 | 1030.59 | 1030.59 | 1030.59 |

SITE: MAITHON DAM

Bulk Density

Sample-9

| | | | | | | |
|---|---|---|---|---|---|---|
| Sand (%) | 0.52 | **Reservoir condition:** | B for Clay | B for Silt | B for Sand | Avg B |
| Silt (%) | 67.84 | Cont. Submerged | 256 | 91 | 0 | 1.43 |
| Clay (%) | 31.63 | Periodic drwadown | 135 | 29 | 0 | 0.62 |
| | | Resvr. normally empty | 0 | 0 | 0 | 0.00 |

| | **Miller's Method** | | | | | | **Lane's Method** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reservoir condition:** | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ |
| Cont. Submerged | 897.37 | 897.61 | 897.77 | 897.89 | 898.00 | 898.00 | 897.80 | 898.05 | 898.23 | 898.37 | 898.48 |
| Periodic drwadown | 956.80 | 956.90 | 956.98 | 957.03 | 957.07 | 957.07 | 956.99 | 957.10 | 957.18 | 957.24 | 957.29 |
| Resvr. normally empty | 988.89 | 988.89 | 988.89 | 988.89 | 988.89 | 988.89 | 988.89 | 988.89 | 988.89 | 988.89 | 988.89 |

Sample-10

| | | | | | | |
|---|---|---|---|---|---|---|
| Sand (%) | 9.20 | **Reservoir condition:** | B for Clay | B for Silt | B for Sand | Avg B |
| Silt (%) | 58.27 | Cont. Submerged | 256 | 91 | 0 | 1.36 |
| Clay (%) | 32.53 | Periodic drwadown | 135 | 29 | 0 | 0.61 |
| | | Resvr. normally empty | 0 | 0 | 0 | 0.00 |

| | **Miller's Method** | | | | | | **Lane's Method** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reservoir condition:** | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ |
| Cont. Submerged | 893.75 | 893.98 | 894.13 | 894.25 | 894.35 | 894.35 | 894.16 | 894.40 | 894.57 | 894.70 | 894.81 |
| Periodic drwadown | 952.57 | 952.67 | 952.74 | 952.80 | 952.84 | 952.84 | 956.99 | 952.86 | 952.94 | 953.00 | 953.04 |
| Resvr. normally empty | 984.42 | 984.42 | 984.42 | 984.42 | 984.42 | 984.42 | 984.42 | 984.42 | 984.42 | 984.42 | 984.42 |

Where,

W1 = Intial bulk density of sediment in kg/$m^3$

W2 = Bulk density of sediment after 2 yrs kg/$m^3$.

W3 = Bulk density of sediment after 3 yrs kg/$m^3$.

W4 = Bulk density of sediment after 4 yrs kg/$m^3$.

W5 = Bulk density of sediment after 5 yrs kg/$m^3$.

W6 = Bulk density of sediment after 6 yrs kg/$m^3$.

### 13.4.4 Kramer's Coefficient:-

SITE: MAITHON DAM
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 | - | - | - | - | - | - | 0.15 | - | - | - |
| 30 | D30 | 0.002 | | 0.002 | 0.002 | - | - | 0.25 | 0.002 | 0.002 | 0.002 |
| 40 | D40 | 0.0035 | 0.003 | 0.003 | 0.0035 | - | - | 0.3 | 0.0035 | 0.005 | 0.004 |
| 50 | D50 | 0.02 | 0.008 | 0.005 | 0.01 | 0.2 | 0.075 | 0.35 | 0.045 | 0.007 | 0.0075 |
| 60 | D60 | 0.055 | 0.055 | 0.018 | 0.04 | 0.38 | 0.36 | 0.41 | 0.055 | 0.01 | 0.015 |
| 70 | D70 | 0.06 | 0.06 | 0.055 | 0.057 | 0.45 | 0.45 | 0.55 | 0.065 | 0.05 | 0.06 |
| 80 | D80 | 0.065 | 0.065 | 0.06 | 0.06 | 0.5 | 0.5 | 1.2 | 0.075 | 0.06 | 0.065 |
| 90 | D90 | 0.07 | 0.07 | 0.065 | 0.065 | 1 | 1 | - | 0.1 | 0.065 | 0.075 |
| 100 | D100 | 4.75 | 4.75 | 4.75 | 4.75 | 4.75 | 4.75 | - | - | 4.75 | 4.75 |
| 84 | D84 | 0.065 | 0.065 | 0.06 | 0.06 | 0.5 | 0.5 | 1.2 | 0.075 | 0.06 | 0.065 |
| 16 | D16 | - | - | - | - | - | - | - | - | - | - |

For Sample-1

| Dia (mm) | Sample-1 | p | Δp | di | dixΔp | Log(dixΔp) |
|---|---|---|---|---|---|---|
| D0 | | 0 | | | | |
| D10 | | 10 | | | | |
| D20 | | 20 | | | | |
| D30 | 0.002 | 30 | | | | |
| D40 | 0.0035 | 40 | 10 | 0.003 | 0.026 | -1.577 |
| D50 | 0.02 | 50 | 10 | 0.008 | 0.084 | -1.077 |
| D60 | 0.055 | 60 | 10 | 0.033 | 0.332 | -0.479 |
| D70 | 0.06 | 70 | 10 | 0.057 | 0.574 | -0.241 |
| D80 | 0.065 | 80 | 10 | 0.062 | 0.624 | -0.204 |
| D90 | 0.07 | 90 | 10 | 0.067 | 0.675 | -0.171 |
| D100 | 4.75 | 100 | 10 | 0.577 | 5.766 | 0.761 |
| D84 | 0.065 | 84 | | | | |
| D16 | | 16 | | | | |

| | | |
|---|---|---|
| da | 0.115 | mm |
| dg | 0.906 | mm |
| σg | - | |
| M | 0.014 | |

**Remarks: Sediment is non-uniform**

SITE: MAITHON DAM
Kramer's coefficient

For Sample-2

| Dia (mm) | Sample-1 | p | Δp | di | dixΔp | Log(dixΔp) |
|---|---|---|---|---|---|---|
| D0 | | 0 | | | | |
| D10 | | 10 | | | | |
| D20 | | 20 | | | | |
| D30 | | 30 | | | | |
| D40 | 0.003 | 40 | | | | |
| D50 | 0.008 | 50 | 10 | 0.005 | 0.049 | -1.310 |
| D60 | 0.055 | 60 | 10 | 0.021 | 0.210 | -0.678 |
| D70 | 0.06 | 70 | 10 | 0.057 | 0.574 | -0.241 |
| D80 | 0.065 | 80 | 10 | 0.062 | 0.624 | -0.204 |
| D90 | 0.07 | 90 | 10 | 0.067 | 0.675 | -0.171 |
| D100 | 4.75 | 100 | 10 | 0.577 | 5.766 | 0.761 |
| D84 | 0.065 | 84 | | | | |
| D16 | | 16 | | | | |

| | | |
|---|---|---|
| da | 0.132 | mm |
| dg | 0.932 | mm |
| σg | - | |
| M | 0.006 | |

**Remarks: Sediment is non-uniform**

For Sample-3

| Dia (mm) | Sample-1 | p | Δp | di | dixΔp | Log(dixΔp) |
|---|---|---|---|---|---|---|
| D0 | | 0 | | | | |
| D10 | | 10 | | | | |
| D20 | | 20 | | | | |
| D30 | 0.002 | 30 | | | | |
| D40 | 0.003 | 40 | 10 | 0.002 | 0.024 | -1.611 |
| D50 | 0.005 | 50 | 10 | 0.004 | 0.039 | -1.412 |
| D60 | 0.018 | 60 | 10 | 0.009 | 0.095 | -1.023 |
| D70 | 0.055 | 70 | 10 | 0.031 | 0.315 | -0.502 |
| D80 | 0.060 | 80 | 10 | 0.057 | 0.574 | -0.241 |
| D90 | 0.065 | 90 | 10 | 0.062 | 0.624 | -0.204 |
| D100 | 4.750 | 100 | 10 | 0.556 | 5.557 | 0.745 |
| D84 | 0.060 | 84 | | | | |
| D16 | | 16 | | | | |

| | | |
|---|---|---|
| da | 0.103 | mm |
| dg | 0.870 | mm |
| σg | - | |
| M | 0.009 | |

**Remarks: Sediment is non-uniform**

SITE: MAITHON DAM
Kramer's coefficient

For Sample-4

| Dia (mm) | Sample-1 | p | Δp | di | dixΔp | Log(dixΔp) |
|---|---|---|---|---|---|---|
| D0 | | 0 | | | | |
| D10 | | 10 | | | | |
| D20 | | 20 | | | | |
| D30 | 0.002 | 30 | | | | |
| D40 | 0.004 | 40 | 10 | 0.003 | 0.026 | -1.577 |
| D50 | 0.010 | 50 | 10 | 0.006 | 0.059 | -1.228 |
| D60 | 0.040 | 60 | 10 | 0.020 | 0.200 | -0.699 |
| D70 | 0.057 | 70 | 10 | 0.048 | 0.477 | -0.321 |
| D80 | 0.060 | 80 | 10 | 0.058 | 0.585 | -0.233 |
| D90 | 0.065 | 90 | 10 | 0.062 | 0.624 | -0.204 |
| D100 | 4.750 | 100 | 10 | 0.556 | 5.557 | 0.745 |
| D84 | 0.060 | 84 | | | | |
| D16 | | 16 | | | | |

| | | |
|---|---|---|
| da | 0.108 | mm |
| dg | 0.891 | mm |
| σg | - | |
| M | 0.011 | |

**Remarks: Sediment is non-uniform**

For Sample-5

| Dia (mm) | Sample-1 | p | Δp | di | dixΔp | Log(dixΔp) |
|---|---|---|---|---|---|---|
| D0 | | 0 | | | | |
| D10 | | 10 | | | | |
| D20 | | 20 | | | | |
| D30 | | 30 | | | | |
| D40 | | 40 | | | | |
| D50 | 0.200 | 50 | | | | |
| D60 | 0.380 | 60 | 10 | 0.276 | 2.757 | 0.440 |
| D70 | 0.450 | 70 | 10 | 0.414 | 4.135 | 0.616 |
| D80 | 0.500 | 80 | 10 | 0.474 | 4.743 | 0.676 |
| D90 | 1.000 | 90 | 10 | 0.707 | 7.071 | 0.849 |
| D100 | 4.750 | 100 | 10 | 2.179 | 21.794 | 1.338 |
| D84 | 0.500 | 84 | | | | |
| D16 | | 16 | | | | |

| | | |
|---|---|---|
| da | 0.810 | mm |
| dg | 1.198 | mm |
| σg | - | |
| M | 0.000 | |

**Remarks: Sediment is non-uniform**

SITE: MAITHON DAM
Kramer's coefficient

For Sample-6

| Dia (mm) | Sample-1 | p | Δp | di | dixΔp | Log(dixΔp) |
|---|---|---|---|---|---|---|
| D0 | | 0 | | | | |
| D10 | | 10 | | | | |
| D20 | | 20 | | | | |
| D30 | | 30 | | | | |
| D40 | | 40 | | | | |
| D50 | 0.075 | 50 | | | | |
| D60 | 0.360 | 60 | 10 | 0.164 | 1.643 | 0.216 |
| D70 | 0.450 | 70 | 10 | 0.402 | 4.025 | 0.605 |
| D80 | 0.500 | 80 | 10 | 0.474 | 4.743 | 0.676 |
| D90 | 1.000 | 90 | 10 | 0.707 | 7.071 | 0.849 |
| D100 | 4.750 | 100 | 10 | 2.179 | 21.794 | 1.338 |
| D84 | 0.500 | 84 | | | | |
| D16 | | 16 | | | | |

| | | |
|---|---|---|
| da | 0.786 | mm |
| dg | 1.185 | mm |
| σg | - | |
| M | 0.000 | |

**Remarks: Sediment is non-uniform**

For Sample-7

| Dia (mm) | Sample-1 | p | Δp | di | dixΔp | Log(dixΔp) |
|---|---|---|---|---|---|---|
| D0 | | 0 | | | | |
| D10 | | 10 | | | | |
| D20 | 0.15 | 20 | | | | |
| D30 | 0.250 | 30 | 10 | 0.194 | 1.936 | 0.287 |
| D40 | 0.300 | 40 | 10 | 0.274 | 2.739 | 0.438 |
| D50 | 0.350 | 50 | 10 | 0.324 | 3.240 | 0.511 |
| D60 | 0.410 | 60 | 10 | 0.379 | 3.788 | 0.578 |
| D70 | 0.550 | 70 | 10 | 0.475 | 4.749 | 0.677 |
| D80 | 1.200 | 80 | 10 | 0.812 | 8.124 | 0.910 |
| D90 | | 90 | | | | |
| D100 | | 100 | | | | |
| D84 | 1.200 | 84 | | | | |
| D16 | | 16 | | | | |

| | | |
|---|---|---|
| da | 0.410 | mm |
| dg | 1.139 | mm |
| σg | - | |
| M | 0.398 | |

**Remarks: Sediment is uniform**

SITE: MAITHON DAM
Kramer's coefficient

For Sample-8

| Dia (mm) | Sample-1 | p | Δp | di | dixΔp | Log(dixΔp) |
|---|---|---|---|---|---|---|
| D0 | | 0 | | | | |
| D10 | | 10 | | | | |
| D20 | | 20 | | | | |
| D30 | 0.002 | 30 | | | | |
| D40 | 0.004 | 40 | 10 | 0.003 | 0.026 | -1.577 |
| D50 | 0.045 | 50 | 10 | 0.013 | 0.125 | -0.901 |
| D60 | 0.055 | 60 | 10 | 0.050 | 0.497 | -0.303 |
| D70 | 0.065 | 70 | 10 | 0.060 | 0.598 | -0.223 |
| D80 | 0.075 | 80 | 10 | 0.070 | 0.698 | -0.156 |
| D90 | 0.100 | 90 | 10 | 0.087 | 0.866 | -0.062 |
| D100 | | 100 | | | | |
| D84 | 0.075 | 84 | | | | |
| D16 | | 16 | | | | |

| | | |
|---|---|---|
| da | 0.047 | mm |
| dg | 0.884 | mm |
| σg | - | |
| M | 0.055 | |

**Remarks: Sediment is non-uniform**

For Sample-9

| Dia (mm) | Sample-1 | p | Δp | di | dixΔp | Log(dixΔp) |
|---|---|---|---|---|---|---|
| D0 | | 0 | | | | |
| D10 | | 10 | | | | |
| D20 | | 20 | | | | |
| D30 | 0.002 | 30 | | | | |
| D40 | 0.005 | 40 | 10 | 0.003 | 0.032 | -1.500 |
| D50 | 0.007 | 50 | 10 | 0.006 | 0.059 | -1.228 |
| D60 | 0.010 | 60 | 10 | 0.008 | 0.084 | -1.077 |
| D70 | 0.050 | 70 | 10 | 0.022 | 0.224 | -0.651 |
| D80 | 0.060 | 80 | 10 | 0.055 | 0.548 | -0.261 |
| D90 | 0.065 | 90 | 10 | 0.062 | 0.624 | -0.204 |
| D100 | 4.750 | 100 | 10 | 0.556 | 5.557 | 0.745 |
| D84 | 0.060 | 84 | | | | |
| D16 | | 16 | | | | |

| | | |
|---|---|---|
| da | 0.102 | mm |
| dg | 0.872 | mm |
| σg | - | |
| M | 0.013 | |

**Remarks: Sediment is non-uniform**

SITE: MAITHON DAM

Kramer's coefficient

For Sample-10

| Dia (mm) | Sample-1 | p | Δp | di | dixΔp | Log(dixΔp) |
|---|---|---|---|---|---|---|
| D0 | | 0 | | | | |
| D10 | | 10 | | | | |
| D20 | | 20 | | | | |
| D30 | 0.002 | 30 | | | | |
| D40 | 0.004 | 40 | 10 | 0.003 | 0.028 | -1.548 |
| D50 | 0.008 | 50 | 10 | 0.005 | 0.055 | -1.261 |
| D60 | 0.015 | 60 | 10 | 0.011 | 0.106 | -0.974 |
| D70 | 0.060 | 70 | 10 | 0.030 | 0.300 | -0.523 |
| D80 | 0.065 | 80 | 10 | 0.062 | 0.624 | -0.204 |
| D90 | 0.075 | 90 | 10 | 0.070 | 0.698 | -0.156 |
| D100 | 4.750 | 100 | 10 | 0.597 | 5.969 | 0.776 |
| D84 | 0.065 | 84 | | | | |
| D16 | | 16 | | | | |

| | | |
|---|---|---|
| da | 0.111 | mm |
| dg | 0.880 | mm |
| σg | - | |
| M | 0.011 | |

**Remarks: Sediment is non-uniform**

Where,

p = Percentage finer in %

da = Arithmetic mean size, mm

dg = Geometric mean size, mm

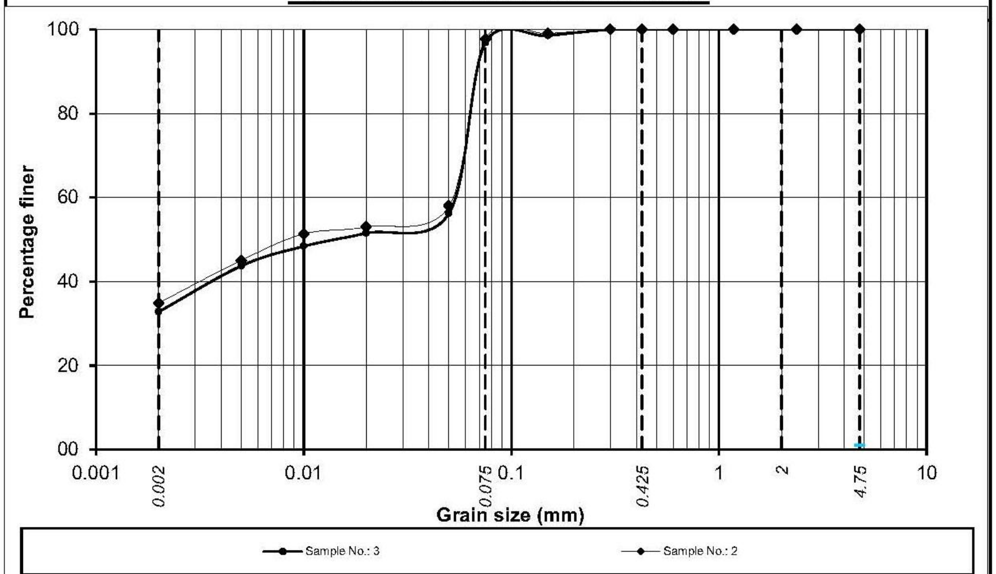
σg = Geometric standard deviation

M = Kramer's uniformity co-efficient

## 13.4.5 Grain Size Distribution curves:-

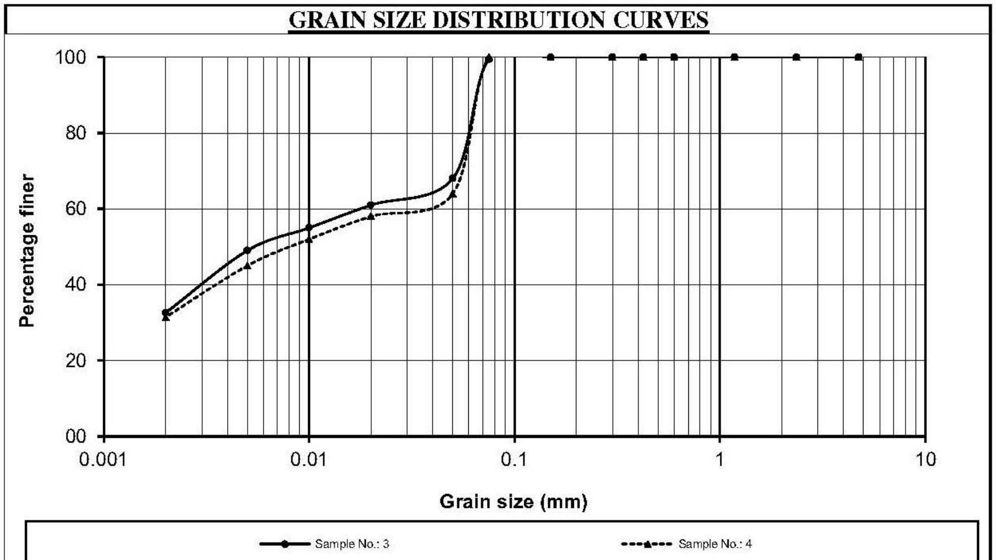
Site: MAITHON DAM (DVC)

GRAIN SIZE DISTRIBUTION CURVES




| Grain size (mm) | <0.002 | 0.002-0.075 | 0.075-4.75 | >4.75 |
|---|---|---|---|---|
| Sample No. | Clay (%) | Silt (%) | Sand (%) | Gravel (%) |
| | 36.75 | 60.09 | 3.16 | 0.00 |
| Sample No.: 2 | 34.83 | 62.87 | 2.30 | 0.00 |

GRAIN SIZE DISTRIBUTION CURVES

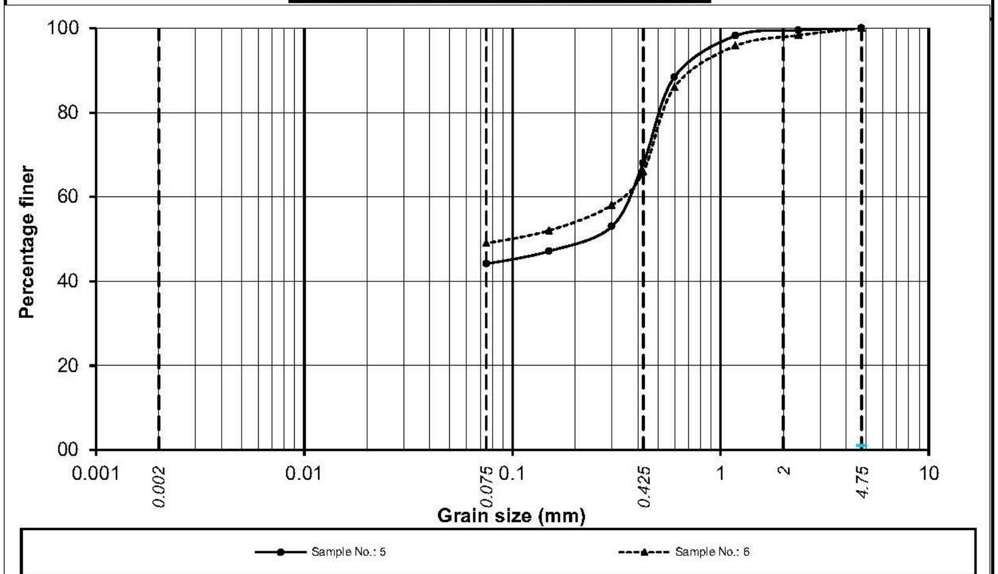



| Grain size (mm) | <0.002 | 0.002-0.075 | 0.075-4.75 | >4.75 |
|---|---|---|---|---|
| Sample No. | Clay (%) | Silt (%) | Sand (%) | Gravel (%) |
| Sample No.: 3 | 32.60 | 66.80 | 0.60 | 0.00 |
| Sample No.: 4 | 31.43 | 68.49 | 0.08 | 0.00 |

*Silt & Clay

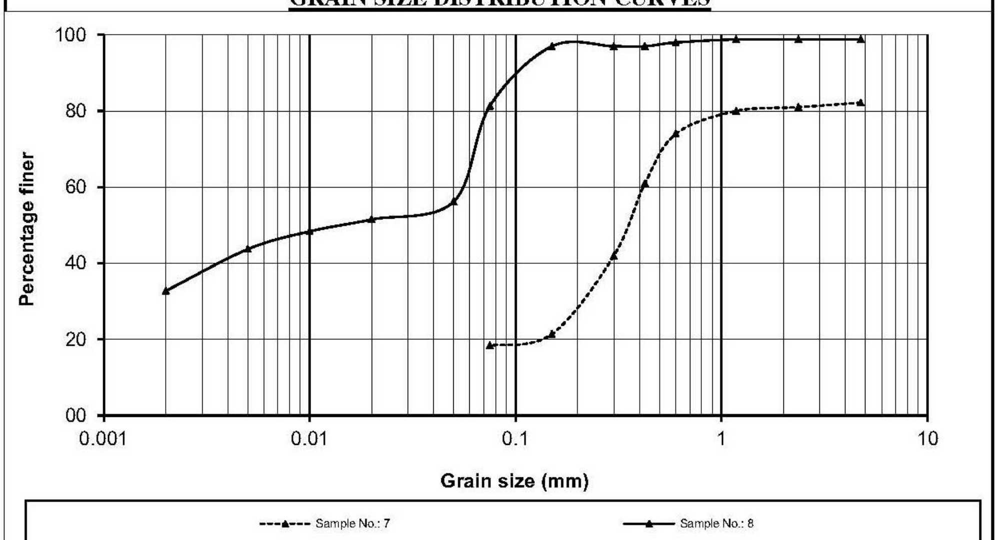
Site: MAITHON DAM (DVC)

## GRAIN SIZE DISTRIBUTION CURVES




| Grain size (mm) | <0.002 | 0.002-0.075 | 0.075-4.75 | >4.75 |
|---|---|---|---|---|
| Sample No. | Clay (%) | Silt (%) | Sand (%) | Gravel (%) |
| Sample No.: 5 | 44.12 | | 55.88 | 0.00 |
| Sample No.: 6 | 50.99 | | 49.01 | 0.00 |

## GRAIN SIZE DISTRIBUTION CURVES

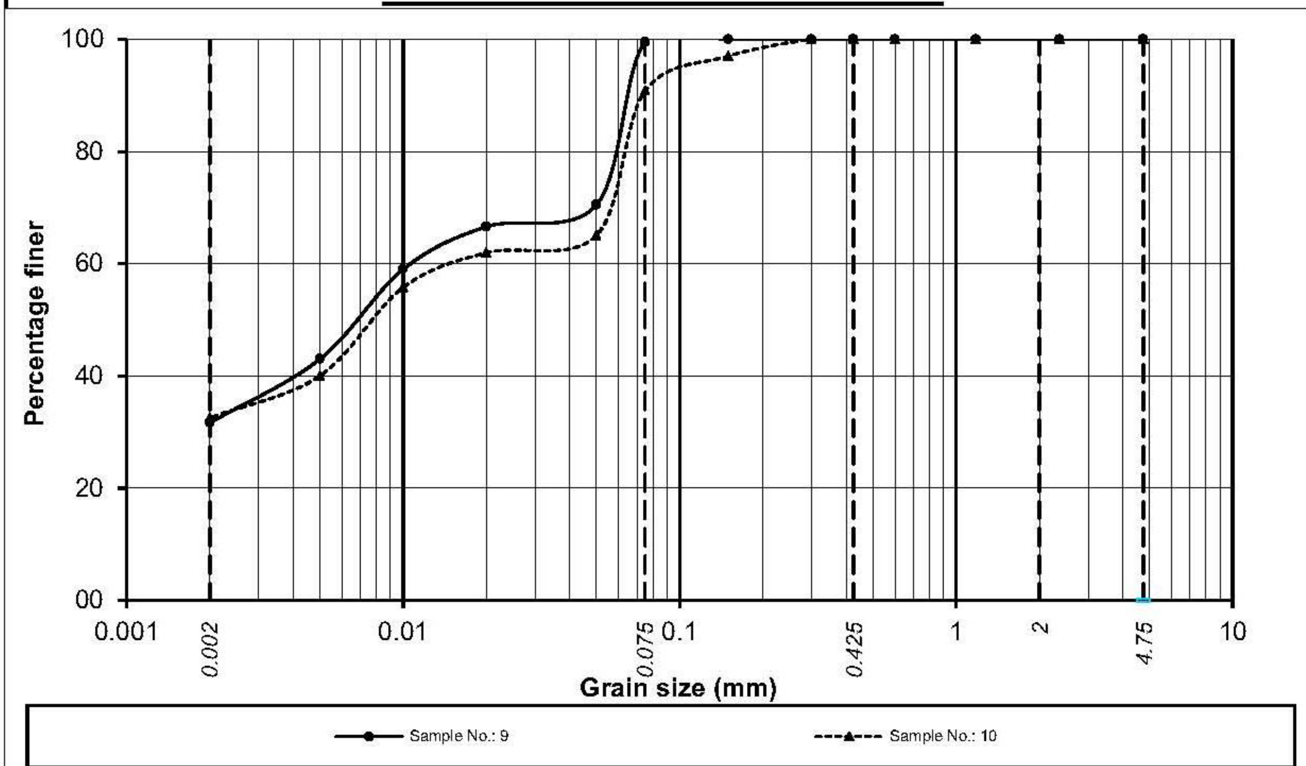



| Grain size (mm) | <0.002 | 0.002-0.075 | 0.075-4.75 | >4.75 |
|---|---|---|---|---|
| Sample No. | Clay (%) | Silt (%) | Sand (%) | Gravel (%) |
| Sample No.: 7 | 18.42 | | 18.42 | 17.80 |
| Sample No.: 8 | 23.46 | 57.86 | 17.51 | 1.17 |

*Silt & Clay

Site: MAITHON DAM (DVC)

## GRAIN SIZE DISTRIBUTION CURVES



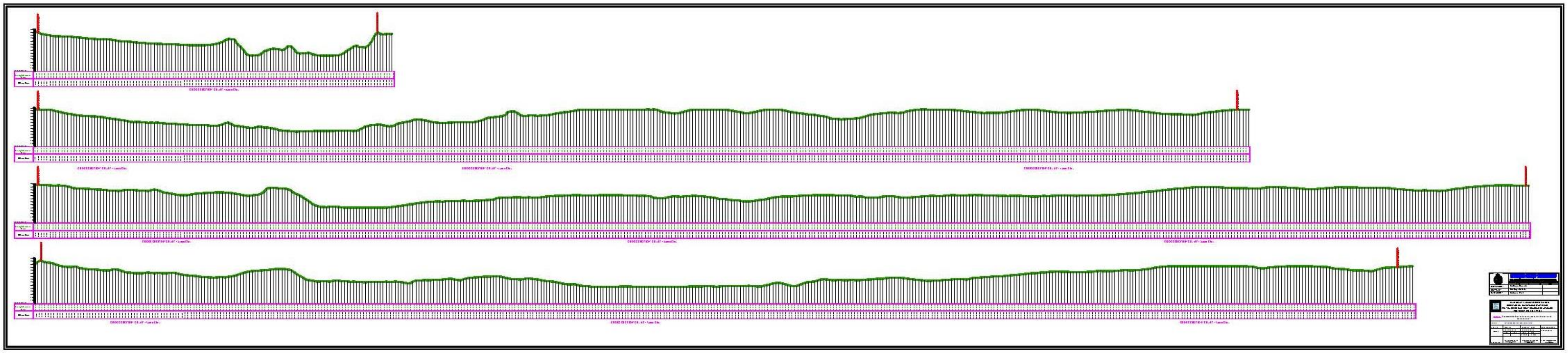

| Grain size (mm) | <0.002 | 0.002-0.075 | 0.075-4.75 | >4.75 |
|---|---|---|---|---|
| **Sample No.** | **Clay (%)** | **Silt (%)** | **Sand (%)** | **Gravel (%)** |
| Sample No.: 9 | 31.64 | 67.84 | 0.52 | 0.00 |
| Sample No.: 10 | 32.53 | 58.27 | 9.20 | 0.00 |

# CROSS SECTIONS (v)

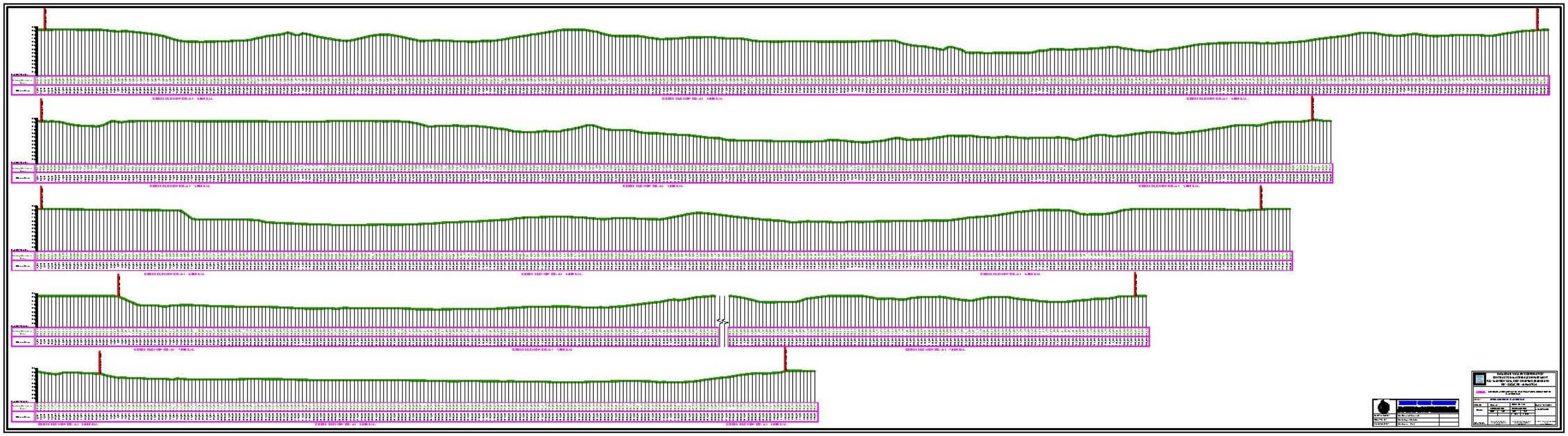
This section has been analyzed the original bed profile, cross section data and cross sectional drawings etc.

# 13.5 Cross Section:-

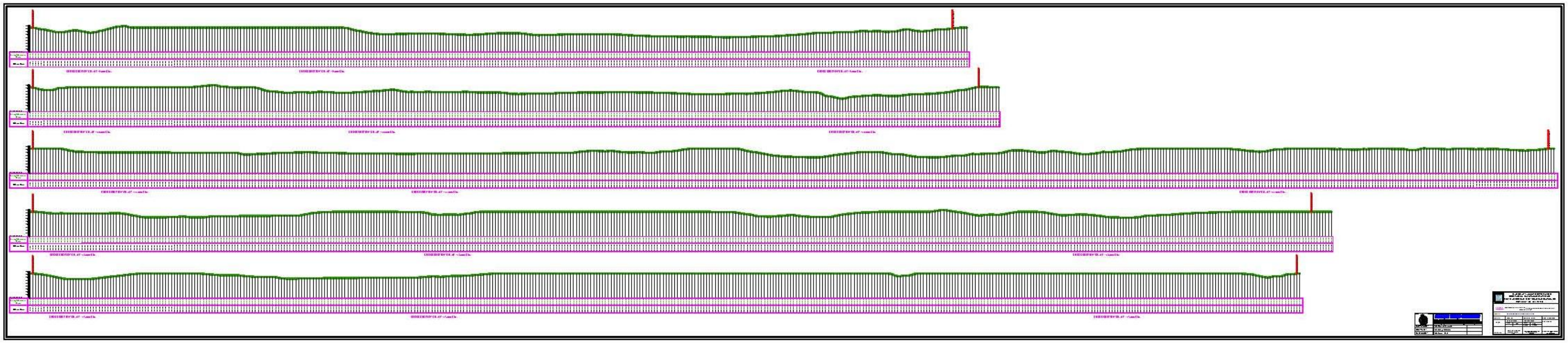
1. **Cross Sectional plan at Chainage 0.00 km to 3.00 km:-**



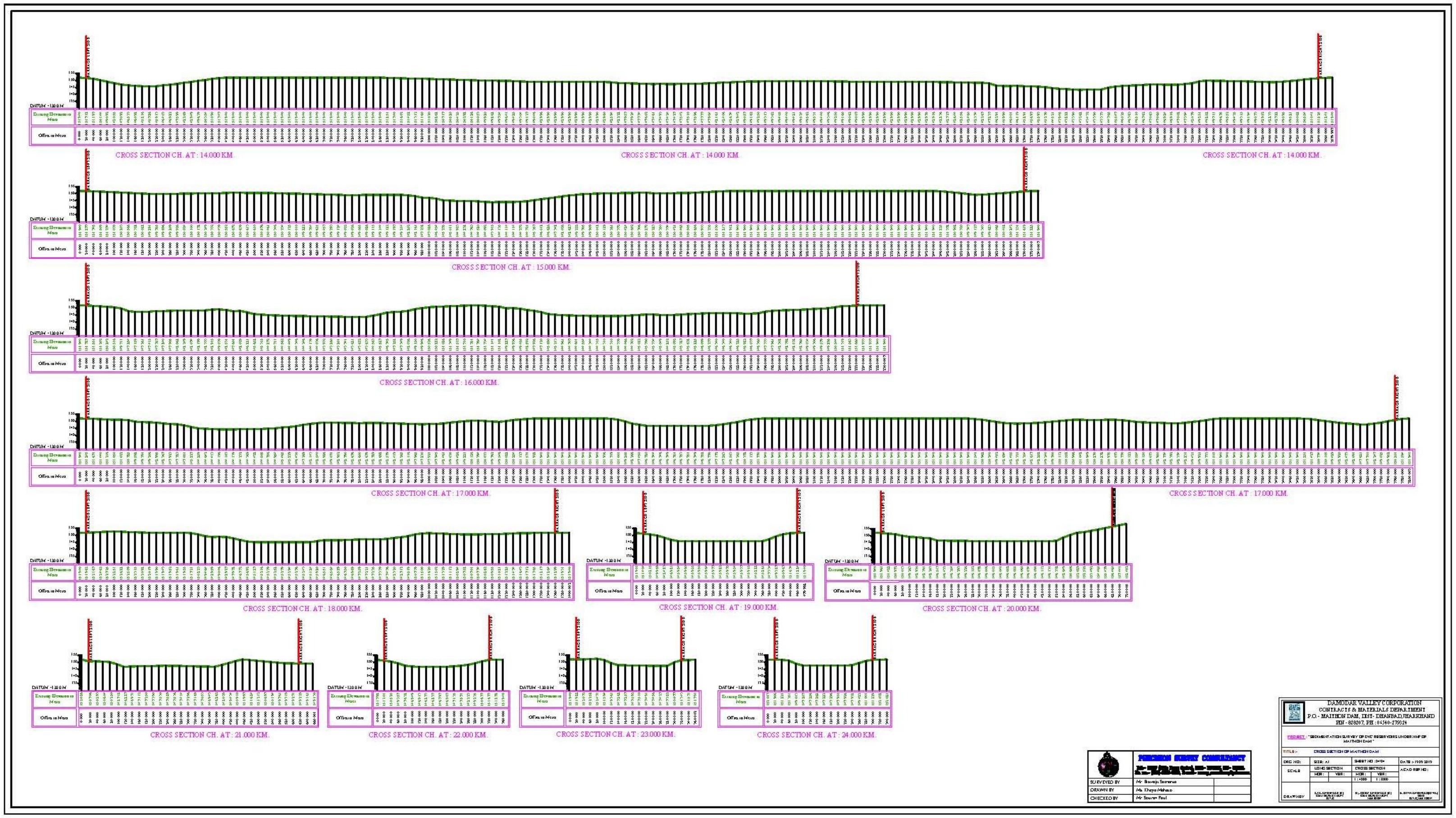
2. **Cross Section at Chainage 4.00 km to 8.00 km:-**



3. **Cross Section at Chainage 9.00 km to 13.00 km:-**



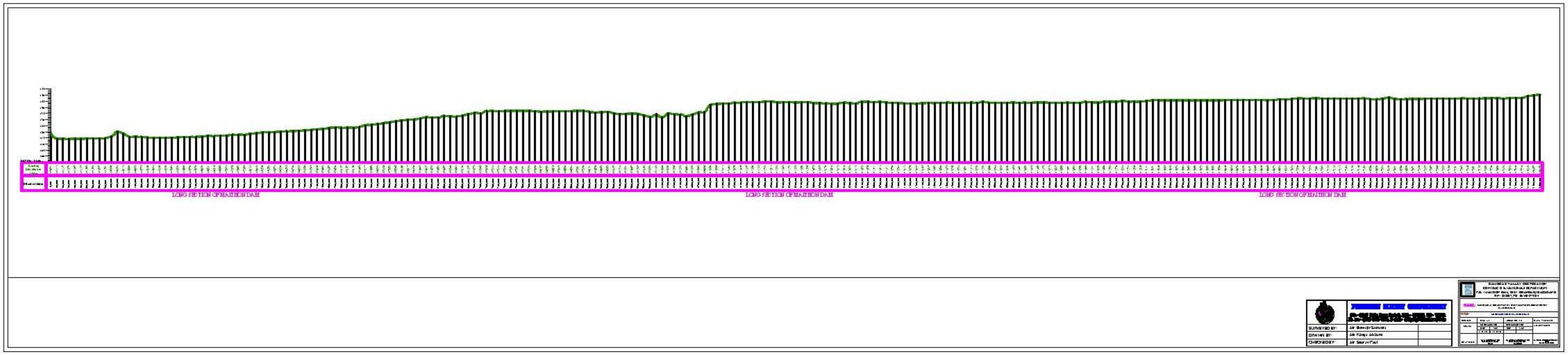
4. **Cross Section at Chainage 14.00 km to 24.00 km:-**



# L- SECTION (vi)

This section has been analyzed longitudinal section drawings.

## 13.6 Long Section of Maithon Reservoir:-



# VERTICAL SEDIMENT DISTRIBUTION (vii)

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

## 13.7 Vertical Sediment Distribution (IS 5477 part-II-1994):-

**This section has been described as per IS 5477 PART-II 1994. "Fixing Capacities of Reservoirs-Dead Storage".**

Reservoirs Sectional Committee, RVD 4

### 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.

*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 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:

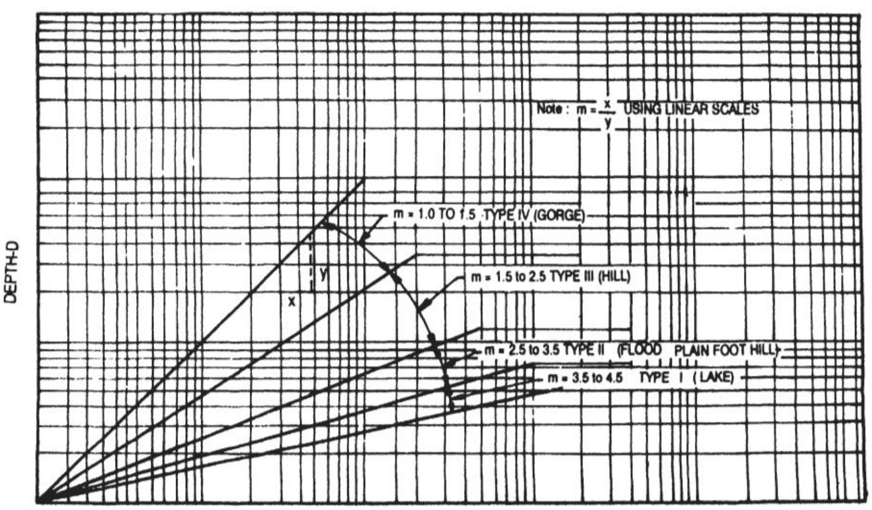
$$A_p = Cp^m (l - p)^n \qquad \text{......(1)}$$

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.



- **Capacity of Maithon Reservoir in different Zones:**

The Below table shows the Capacity of Maithon Reservoir in different allocated zones for different years. This shows Progressive reduction of storage capacity in all zones in 2019.

| CAPACITY OF MAITHON RESERVOIR IN DIFFERENT ZONE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ZONE<br>YEAR | CAPACITY IN ACRE FT. (MM$^3$) | | | | | | | | |
| | 1955 | 1963 | 1965 | 1971 | 1979 | 1987 | 1994 | 2002 | 2019 |
| DEAD STORAGE UPTO EL. 132.6 M | 167430 (206.5) | 140365 (173.1) | 135547 (167.2) | 130732 (161.3) | 112455 (138.7) | 95099 (117.3) | 76920 (94.88) | 75550 (93.20) | 72802.04 (89.80) |
| LIVE STORAGE EL. 132.6-146.3 M | 492307 (607.3) | 465322 (574.6) | 460956 (568.6) | 441472 (544.5) | 425252 (524.5) | 398478 (491.5) | 381820 (470.98) | 357860 (441.52) | 348322.92 (429.65) |
| FLOOD ZONE EL. 146.3-150.9 M | 309766 (382.1) | 312635 (385.6) | 313170 (386.3) | 308746 (380.8) | 306365 (377.9) | 301665 (372.1) | 296495 (365.73) | 270570 (333.83) | 263952 (325.58) |
| OVERALL UPTO EL. 150.9 M | 969503 (1195.9) | 918322 (1132.7) | 909673 (1122.1) | 881000 (1086.6) | 844072 (1041.1) | 795242 (980.9) | 755235 (931.5) | 703980 (868.57) | 685076.96 (845.03) |

- **Sedimentation in Different zones viz. Flood zone, live zone and Dead zone:-**

| EL IN M. | CAP IN MCM | | CAP-LOSS 2002-2019 |
|---|---|---|---|
| | 2002 | 2019 | |
| 150.9 | 868.35 | 845.03 | 23.32 |
| 150.0 | 787.80 | 771.47 | 16.33 |
| 147.0 | 571.35 | 560.62 | 10.73 |
| 146.3 | 534.60 | 519.45 | 15.15 |
| 146.0 | 517.38 | 502.66 | 14.72 |
| 143.0 | 365.69 | 356.28 | 9.41 |
| 139.0 | 219.09 | 210.92 | 8.17 |
| 136.0 | 145.25 | 143.00 | 2.25 |
| 132.6 | 93.19 | 89.80 | 3.39 |
| 132.0 | 85.53 | 82.83 | 2.70 |
| 129.0 | 55.49 | 53.69 | 1.80 |
| 128.0 | 48.33 | 45.55 | 2.78 |
| 125.0 | 29.52 | 26.24 | 3.28 |
| 122.0 | 16.32 | 13.33 | 2.99 |
| 121.0 | 13.51 | 9.99 | 3.52 |
| 118.0 | 6.18 | 3.09 | 3.09 |
| 113.0 | 0.00 | 0.00 | 0.00 |

| **LOSS OF CAP IN FLOOD ZONE** | | | |
|---|---|---|---|
| EL | 150.9 | 146.3 | LIVE CAP |
| YEAR | CAP IN MCM | | |
| 2002 | 868.35 | 534.60 | 333.75 |
| 2019 | 845.03 | 519.45 | 325.58 |
| **LOSS OF CAP IN FLOOD ZONE** | | | **8.17** |

| **LOSS OF CAP IN LIVE ZONE** | | | |
|---|---|---|---|
| EL | 146.3 | 132.6 | LIVE CAP |
| YEAR | CAP IN MCM | | |
| 2002 | 534.60 | 93.19 | 441.41 |
| 2019 | 519.45 | 89.80 | 429.65 |
| **LOSS OF CAP IN LIVE ZONE** | | | **11.76** |

| **LOSS OF CAP IN DEAD ZONE** | | | |
|---|---|---|---|
| EL | 132.6 | 113 | LIVE CAP |
| YEAR | CAP IN MCM | | |
| 2002 | 93.19 | 0.00 | 93.19 |
| 2019 | 89.80 | 0.00 | 89.80 |
| **LOSS OF CAP IN DEAD ZONE** | | | **3.39** |

**Total Loss of Capacity- 23.32 MCM (18905 Acre Feet)**

- **Percent loss of Capacity in Maithon Reservoir:-**

| Percent loss of Capacity in Maithon Reservoir | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Zone / Period | Total loss percent | | | | | | | | Average Annual loss percent | | | | | | | |
| | 55-63 | 55-65 | 55-71 | 55-79 | 55-87 | 55-94 | 1955-2002 | 1955-2019 | 55-63 | 55-65 | 55-71 | 55-79 | 55-87 | 55-94 | 1955-2002 | 1955-2019 |
| Dead Storage upto El. 132.6m | 16.16 | 19.04 | 21.89 | 32.83 | 43.2 | 54.04 | 54.72 | 56.51 | 2 | 1.9 | 1.4 | 1.4 | 1.4 | 1.39 | 1.16 | 0.88 |
| Live Storage El. 132.6m - 146.3m | 5.48 | 6.37 | 10.33 | 13.62 | 19.06 | 22.44 | 27.3 | 29.25 | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | 0.57 | 0.58 | 0.46 |
| Flood Zone EL. 146.3m - 150.9m | Negligible | | | 0.8 | 2.61 | 4.28 | 12.63 | 14.79 | Negligible | | | | | | 0.27 | 0.23 |
| Overall | 4.7 | 5.4 | 8.1 | 11.5 | 15.9 | 19.59 | 27.37 | 29.34 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.46 |

- **Average Annual Volume of Deposit in Maithon Reservoir** :-

| AVERAGE ANNUAL VOLUME OF DEPOSIT IN MAITHON RESERVOIR IN ACRE FEET/$MM^3$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **YEAR** | **1963** | **1965** | **1971** | **1979** | **1987** | **1994** | **2002** | **2019** |
| **1955** | 6398 (7.89) | 5983 (7.38) | 5531 (6.82) | 5226 (6.45) | 5446 (6.72) | 5494 (6.77) | 5649 (6.96) | 4444 (5.48) |
| **1963** | - | 4325 (5.33) | 4665 (5.75) | 4641 (5.72) | 5128 (6.33) | 5261 (6.48) | 5358 (6.61) | 4165 (5.14) |
| **1965** | - | - | 4778 (5.89) | 4686 (5.78) | 5201 (6.42) | 5325 (6.56) | 5412 (6.67) | 4159 (5.13) |
| **1971** | - | - | - | 4616 (5.69) | 5360 (6.61) | 5468 (6.74) | 5532 (6.82) | 4082 (5.03) |
| **1979** | - | - | - | - | 6104 (7.53) | 5922 (7.30) | 5837 (7.02) | 3975 (4.90) |
| **1987** | - | - | - | - | - | 5715 (7.04) | 5703 (7.03) | 3443 (4.25) |
| **1994** | - | - | - | - | - | - | 5695 (7.02) | 2806 (3.46) |
| **2002** | - | - | - | - | - | - | - | 1112 (1.37) |
| **2019** | - | - | - | - | - | - | - | - |

# CONTOUR MAP (viii)

**This section has been indicated contour map of Maithon Reservoir**

## 13.8 Contour Elevation & Area of Maithon Reservoir:-

| Contour Elevation (m) | Area in Sq. M. | Area in Sq. Km. | Contour Elevation (m) | Area in Sq. M. | Area in Sq. Km. |
|---|---|---|---|---|---|
| 113.0 | 31.35 | 0 | 124.4 | 4872118.718 | 4.87 |
| 113.3 | 123.95 | 0 | 124.7 | 5035685.54 | 5.04 |
| 113.6 | 216.55 | 0 | 125.0 | 5199252.361 | 5.2 |
| 113.9 | 309.14 | 0 | 125.3 | 5393749.778 | 5.39 |
| 114.0 | 401.74 | 0 | 125.6 | 5588247.195 | 5.59 |
| 114.2 | 76835.51 | 0.08 | 125.9 | 5782744.612 | 5.78 |
| 114.5 | 153269.28 | 0.15 | 126.0 | 5977242.029 | 5.98 |
| 114.8 | 229703.05 | 0.23 | 126.2 | 6191603.421 | 6.19 |
| 115.0 | 306136.82 | 0.31 | 126.5 | 6405964.813 | 6.41 |
| 115.1 | 424870.65 | 0.42 | 126.8 | 6620326.204 | 6.62 |
| 115.4 | 543604.48 | 0.54 | 127.0 | 6834687.596 | 6.83 |
| 115.7 | 662338.32 | 0.66 | 127.1 | 7072113.258 | 7.07 |
| 116.0 | 781072.15 | 0.78 | 127.4 | 7309538.921 | 7.31 |
| 116.3 | 883717.98 | 0.88 | 127.7 | 7546964.583 | 7.55 |
| 116.6 | 986363.81 | 0.99 | 128.0 | 7765584.007 | 7.77 |
| 116.9 | 1089009.64 | 1.09 | 128.3 | 7987837.629 | 7.99 |
| 117.0 | 1191655.46 | 1.19 | 128.6 | 8210091.25 | 8.21 |
| 117.2 | 1296761.14 | 1.3 | 128.9 | 8432344.872 | 8.43 |
| 117.5 | 1401866.82 | 1.4 | 129.0 | 8506429.412 | 8.51 |
| 117.8 | 1506972.50 | 1.51 | 129.2 | 8731844.844 | 8.73 |
| 118.0 | 1612078.18 | 1.61 | 129.5 | 9069967.993 | 9.07 |
| 118.1 | 1709075.96 | 1.71 | 129.8 | 9408091.142 | 9.41 |
| 118.4 | 1806073.74 | 1.81 | 130.0 | 9633506.574 | 9.63 |
| 118.7 | 1903071.53 | 1.9 | 130.1 | 9652557.837 | 9.65 |
| 119.0 | 2000069.31 | 2 | 130.4 | 9709711.626 | 9.71 |
| 119.3 | 2143250.38 | 2.14 | 130.7 | 9766865.414 | 9.77 |
| 119.6 | 2286431.44 | 2.29 | 131.0 | 9824019.203 | 9.82 |
| 119.9 | 2429612.51 | 2.43 | 131.3 | 10133959.98 | 10.13 |
| 120.0 | 2572793.57 | 2.57 | 131.6 | 10443900.75 | 10.44 |
| 120.2 | 2697999.89 | 2.7 | 131.9 | 10753841.53 | 10.75 |
| 120.5 | 2823206.21 | 2.82 | 132.0 | 10857155.12 | 10.86 |
| 120.8 | 2948412.52 | 2.95 | 132.2 | 11373496.5 | 11.37 |

| Contour Elevation (m) | Area in Sq. M. | Area in Sq. Km. | Contour Elevation (m) | Area in Sq. M. | Area in Sq. Km. |
|---|---|---|---|---|---|
| 121.0 | 3073618.84 | 3.07 | 132.5 | 12148008.58 | 12.15 |
| 121.1 | 3189819.59 | 3.19 | 132.6 | 12406179.27 | 12.41 |
| 121.4 | 3306020.34 | 3.31 | 132.8 | 12922520.66 | 12.92 |
| 121.7 | 3422221.09 | 3.42 | 133.0 | 13438862.04 | 13.44 |
| 122.0 | 3538421.84 | 3.54 | 133.1 | 13597259.85 | 13.6 |
| 122.3 | 3647223.64 | 3.65 | 133.4 | 14072453.26 | 14.07 |
| 122.6 | 3756025.45 | 3.76 | 133.7 | 14547646.67 | 14.55 |
| 122.9 | 3864827.25 | 3.86 | 134.0 | 15022840.08 | 15.02 |
| 123.0 | 3973629.06 | 3.97 | 134.3 | 15665122.85 | 15.67 |
| 123.2 | 4116468.06 | 4.12 | 134.6 | 16307405.62 | 16.31 |
| 123.5 | 4259307.07 | 4.26 | 134.9 | 16949688.39 | 16.95 |
| 123.8 | 4402146.07 | 4.4 | 135.0 | 17163782.65 | 17.16 |
| 124.0 | 4544985.08 | 4.54 | 135.2 | 17380456.59 | 17.38 |
| 124.1 | 4708551.90 | 4.71 | 135.5 | 17705467.5 | 17.71 |

| Contour Elevation (m) | Area in Sq. M. | Area in Sq. Km. | Contour Elevation (m) | Area in Sq. M. | Area in Sq. Km. |
|---|---|---|---|---|---|
| 135.8 | 18030478.41 | 18.03 | 147.2 | 62107239.25 | 62.11 |
| 136.0 | 18247152.35 | 18.25 | 147.5 | 64104532.12 | 64.1 |
| 136.1 | 18479788.35 | 18.48 | 147.8 | 66101824.99 | 66.1 |
| 136.4 | 19177696.33 | 19.18 | 148.0 | 67433353.57 | 67.43 |
| 136.7 | 19875604.32 | 19.88 | 148.1 | 68041653.45 | 68.04 |
| 137.0 | 20573512.31 | 20.57 | 148.4 | 69866553.08 | 69.87 |
| 137.3 | 21653230.33 | 21.65 | 148.7 | 71691452.71 | 71.69 |
| 137.6 | 22732948.35 | 22.73 | 149.0 | 73516352.34 | 73.52 |
| 137.9 | 23812666.38 | 23.81 | 149.3 | 75169952.94 | 75.17 |
| 138.0 | 24172572.38 | 24.17 | 149.6 | 76823553.54 | 76.82 |
| 138.2 | 24957616.89 | 24.96 | 149.9 | 78477154.14 | 78.48 |
| 138.5 | 26135183.65 | 26.14 | 150.0 | 79028354.34 | 79.03 |
| 138.8 | 27312750.42 | 27.31 | 150.2 | 80232768.05 | 80.23 |
| 139.0 | 28097794.92 | 28.1 | 150.5 | 82039388.62 | 82.04 |
| 139.1 | 28677282.99 | 28.68 | 150.8 | 83846009.19 | 83.85 |
| 139.4 | 30415747.19 | 30.42 | 150.9 | 84448216.04 | 84.45 |

| Contour Elevation (m) | Area in Sq. M. | Area in Sq. Km. | | Contour Elevation (m) | Area in Sq. M. | Area in Sq. Km. |
|---|---|---|---|---|---|---|
| 139.7 | 32154211.39 | 32.15 | | 151.2 | 88328561.49 | 88.33 |
| 140.0 | 33892675.59 | 33.89 | | 151.5 | 92625906.94 | 92.63 |
| 140.3 | 34753078.37 | 34.75 | | 151.8 | 97108732.38 | 97.11 |
| 140.6 | 35613481.14 | 35.61 | | 152.1 | 101311597.8 | 101.31 |
| 140.9 | 36473883.92 | 36.47 | | 152.4 | 105452443.3 | 105.45 |
| 141.0 | 36760684.85 | 36.76 | | - | - | - |
| 141.2 | 37306905.27 | 37.31 | | - | - | - |
| 141.5 | 38126235.9 | 38.13 | | - | - | - |
| 141.8 | 38945566.54 | 38.95 | | - | - | - |
| 142.0 | 39491786.96 | 39.49 | | - | - | - |
| 142.1 | 39774607.54 | 39.77 | | - | - | - |
| 142.4 | 40623069.28 | 40.62 | | - | - | - |
| 142.7 | 41471531.02 | 41.47 | | - | - | - |
| 143.0 | 42319992.76 | 42.32 | | - | - | - |
| 143.3 | 43527393.22 | 43.53 | | - | - | - |
| 143.6 | 44734793.67 | 44.73 | | - | - | - |
| 143.9 | 45942194.13 | 45.94 | | - | - | - |
| 144.0 | 46344660.95 | 46.34 | | - | - | - |
| 144.2 | 47336970.5 | 47.34 | | - | - | - |
| 144.5 | 48825434.82 | 48.83 | | - | - | - |
| 144.8 | 50313899.13 | 50.31 | | - | - | - |
| 145.0 | 51306208.68 | 51.31 | | - | - | - |
| 145.1 | 51689646.49 | 51.69 | | - | - | - |
| 145.4 | 52839959.92 | 52.84 | | - | - | - |
| 145.7 | 53990273.34 | 53.99 | | - | - | - |
| 146.0 | 55140586.77 | 55.14 | | - | - | - |
| 146.3 | 56831123.94 | 56.83 | | - | - | - |
| 146.6 | 58521661.11 | 58.52 | | - | - | - |
| 146.9 | 60212198.28 | 60.21 | | - | - | - |
| 147.0 | 60775710.67 | 60.78 | | - | - | - |

# 13.8.1 Contour Plan of Maithon Reservoir:-

# TRAP EFFICIENCY (ix)

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

## 13.9 Trap Efficiency of reservoir (IS 12182-1987):-

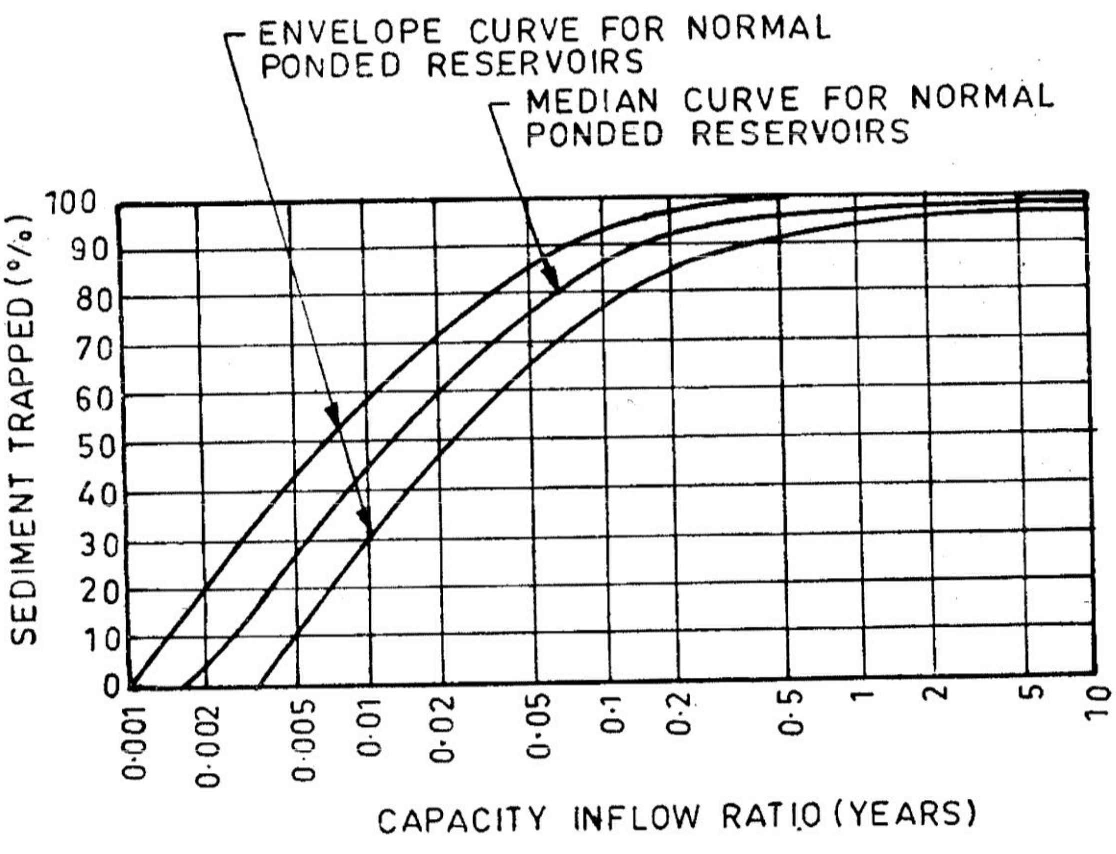
The Trap efficiency of Maithon reservoir has been calculated according to Brune'S trap efficiency curve as per I.S 12182-1987 "Guidelines for determination of effects of sedimentation of Effects of sedimentation in planning and performance of Reservoirs".

Trap efficiency is defined as the percentage of the sediment deposited in the reservoir even inspite of taking precautions and measures to control its deposition.

Therefore, trap Efficiency:

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

Trap efficiency of a reservoir, over a period is the ratio of the total deposited sediment inflow. Gunnar Brune analyzed data from the Reservoirs 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 -




**BRUNE'S CURVE**

- **Reservoir Data:-**

a) Full Reservoir level (FRL)=150.9m
b) Mean operating Pool elevation = 146.3m
c) Capacity at FRL, C1= 845.03 MCM
d) Capacity at mean Operating Pool elevation, C2 = 566.27 MCM
e) Average inflow, I, over the study period of 10 years, in volume-tric units= 3926.31
f) Length of Reservoir, L, at the mean operating level=24000m

- **Brune'S Method:-**

**Capacity Inflow ratio**

**C1/I= 845.03/3926.31= 0.215 year**

**Trap efficiency corresponding to above ratio C/I as read from median curve for normally ponded reservoir = 92 percent**

# CHARTS/DRAWINGS (x)

## 13.10 Charts/Drawing:-

# 13.10.1 Grid Plan of Maithon Reservoir:-

# 13.10.2 Topographical Plan of maithon Reservoir:-

# CONCLUSIONS/RECOMMENDATIONS

## 14.0 Conclusion:-

It can be seen that on the basis of 1/500th of the volume of monsoon flow along, the deposition rate cannot be adequately worked out, as it will further require information on volume of water flow, bed load, trap efficiency and unit weight of deposited sediment. It appears, however , that 1/500th of the volume of monsoon flow was considered as the overall deposition rate which amount to 5110.21 acre feet ( 6.30 million $m^3$) of annual deposit on the basis of 2555104.09 acre feet (3151.67 million $m^3$) of monsoon flow (1955 to 2019). Taking 2010 square miles (5046 square km) as the net sediment producing area, the average annual deposition rate works out to 2.54 acre feet per square miles (1210.6 $m^3/km^2$) of the catchment area.

## 14.1 Recommendations:-

Remembering the emerging problems of riverine flood, we have mentioned that the current factors of flood risk of lower Damodar River are as follows: (1) bottle-neck and physically handicapped location of lower Damodar Basin in the Gangetic West Bengal (huge volume of channel flow collected from funnel-shaped rocky upper catchment passing through narrow and shallow reach of lower Damodar) including the tidal effect of lower reach, (2) three to four days continuous heavy rainfall due to SW-NE directional monsoonal depressions, (3) uncontrolled runoff of upper catchment, (4) increasing siltation of dams, barrages, canals, and river beds, (5) only four large dams (i.e., Tilaiya, Konar, Maithon, and Panchet), Tenughat Reservoir, and Durgapur Barrage serving the purpose of all proposed eight large dams and combined flood moderation capacity of Maithon and Panchet dams reducing up to only 32 per cent, (6) the dams compelling to release excess water in the month of late September because of already storing water in the previous months of monsoon, (7) annual peak discharge of short duration occurring in between late September and October at the time of over-saturation of alluvial soils, ground water and existing streams, and (8) drainage congestion and encroachment of active river bed and floodplain.

From the perspective of flood climate, the recurrent floods of Damodar River is directly influenced by rainstorms of 3- to 4-day duration, path of cyclone, extreme rainfall event of 3 to 6 hours, runoff yield, and discharging of excess water from the upstream dams and Durgapur barrage. From the standpoint of flood hydrology, the stream flow during high magnitude floods in our study area is primarily confined within bank full level, with occasional overtopping of the levees. The floodplain flow, whenever it took place, is intermittent in nature. To manage floods, we should focus on the travel time of flood waves from Durgapur barrage to the downstream end and on the up-to-date accurate estimation of critical bank full discharge at the ungauged sites of lower Damodar River.

From the above analysis, it is understood that observing the drawbacks of large scale Damodar Valley Planning, we can only predict or manage the flood discharge to a certain level, not stopping it completely. So scrutinizing the exiting framework of basin planning, it is the exact time to rethink the increasing flood risk of lower Damodar River and renovation of Damodar Valley Planning in West Bengal in the frame of global warming and climate change. It is also found that the large scale deposition will affect the area in near future. So, flood will become devastating in nature.

From the above analysis, it is understood that observing the drawbacks of large scale Damodar Valley Planning, we can only predict or manage the flood discharge to a certain level, not stopping it completely. So scrutinizing the exiting framework of basin planning, it is the exact time to rethink the increasing flood risk of lower Damodar River and renovation of Damodar Valley Planning in West Bengal in the frame of global warming and climate change. It is also found that the large scale deposition will affect the area in near future. So, flood will become devastating in nature. The Recommendation is also described in the following:-

i) **The study also reflects that in future the flood zone and live storage will increase up to 35% and 50% respectively**.

ii) **The volume of sediment deposit will decrease up to 34% in 100 years due to lack of flow in summer time.**

iii) **From source the most of the deposition will find near 6-8 mile reach with the rate of 24.60 % increase**.

## *Control of sediment deposition:-*

The deposition of sediment in a reservoir 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 reservoirs 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 reservoir 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 reservoir. 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 reservoir 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 reservoir 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 reservoirs 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 reservoir 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 reservoir.

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 reservoirs, where only a small fraction of the total annual flow can be stored;

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

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

4. Draining and Flushing:-

The method involves relatively slow release of all stored water in a reservoir 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 reservoirs.

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 reservoir 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.

6. Sluicing with Hydraulics and Mechanical Agitation :-

Methods that stir up, break up or move deposits of a sediment into a stream current moving through a drained reservoir basin or into a full reservoir will tend to make the removal of sediment from the reservoir 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 reservoir basin should be considered. It has, however, limited application.

## 15.0 Personnel:-

The Following Personnel were associated with the Sedimentation Survey of Maithon Reservoir:-

- **Survey:**
  1. Shri Baidyanath Pal, Surveyor
  2. Shri Biswajit Samanta, Surveyor
  3. Shri Rakhe hari Das, Surveyor

- **Checked by the Following Personnel:**
  1. Shri Nasim Ansari, Sr.Divisional Engineer (C), Hydraulic Data Division, DVC, Maithon
  2. Shri Atul Kumar Singh, Executive Engineer, (Civil), Hydraulic Data Division, DVC, Maithon
  3. Shri Basudev Das , Surveyor, Grade-I, PG-II, Hydraulic Data Division, DVC, Maithon

- **Approved By:**
  1. Shri S.K.Maji, DCE (Civil), W/R, DVC, Maithon

All the Report have been furnished as per given guide lines mentioned in TOR.

## 15.1 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)**

**Name-Bimalendu Ghosh**

**Designation- Senior Survey Consultant**

**The Institution of Surveyors (Delhi)**

## 15.2 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.)
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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<br>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)<br>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)<br>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)

HYDRO SOLUTIONS RIVER RESEARCH

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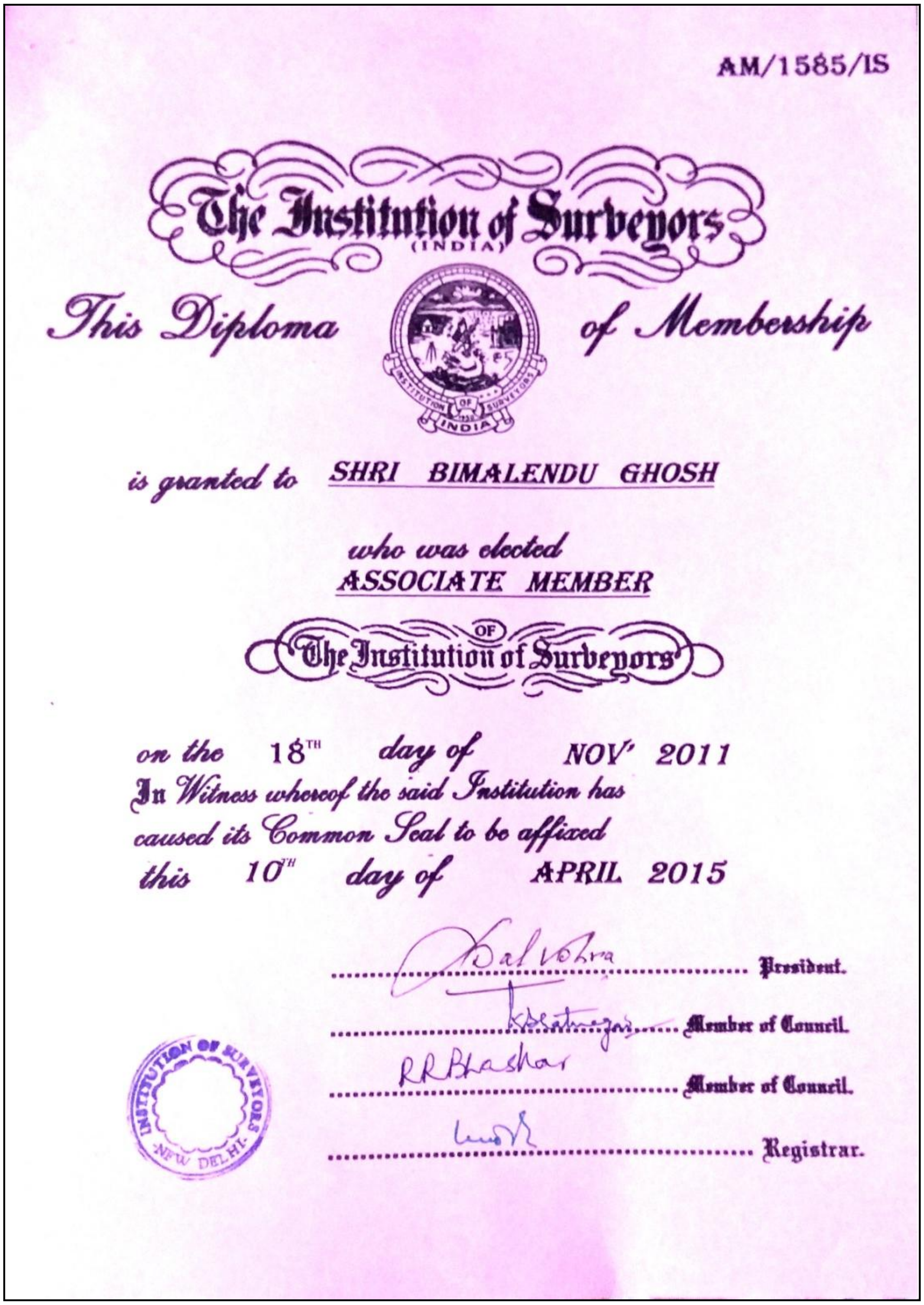
15.3 Certificate of Bimalendu Ghosh:-



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

Bal Vohra ........ President.

........ Member of Council.

R R Bhaskar ........ Member of Council.

........ Registrar.

INSTITUTION OF SURVEYORS NEW DELHI

# SITE IMAGES

## 16.0 Site Images:-