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

"Sedimentation Survey Report of Salaulim Dam under NHP"

SALAULIM DAM
LAT:- 15°13'0.00"N
LONG:- 74°11'0.00"E

Survey Period: 20th January to 18th February, 2021

Surveyed by:-

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

ACKNOWLEDGEMENT

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

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

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

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Executive Summary:-

Sedimentation not only occurs in the dead storage but also encroaches into the live storage, which impairs the intended benefits from the reservoirs by causing more drought, flooding, Aggradations of upstream channels, increase in GW table leading water logging and soil sanitization, and degradation of downstream channel and riparian habitat. Therefore, the problem of sedimentation needs clear understanding and careful consideration as it impairs the desired functionality of the dams. Goa has taken up the task of conducting Sedimentation Survey for Salaulim Dam of Goa under NHP Following work is done:

- Estimation and study of the sedimentation behavior of reservoirs in different zones including horizontal zones throughout the reservoirs as well as vertical zones namely (a) dead storage(b) live storage (c) flood storage, if any

- Conducting Bathymetry/ hydrographic survey of reservoir area (submerge portion) (50m x 50 m grid) and topographic survey of non submerge portion (50m x 50 m Grid)

- Upgrading the Elevation-Area-Capacity tables /curves of reservoirs at regular intervals. Capacity loss of reservoirs

- Assessment and review of life expectancy of reservoirs, Find of new zero elevation of reservoir, sediment inflow rate, Preparation of Contour maps of bed. Bed and suspended sediment analysis, Preparation Long section of reservoir and Cross section of reservoir at various interval

- Recommendation of suitable measures for removal of sediment and future remedies

This report contents different section describing the detailed analysis fulfilling the aforesaid work. **Section 1** describes work order basic description of dam, hydrology. Salulim dam is a composite structure of earth cum masonry type of 42.5 meters (139.44 ft) height with a catchment area of 209.04 Sq.km (80.71 Sq. miles). The primary purposes of Salaulim Dam are Irrigation and water supplies. **Section 2** briefs cause of sedimentation.

Section 3 contents location map of the area and **section 4** describes detailed scope of work of the project. For the Topographic / Hydrography Survey, the Level has been

carried out from the GTS Pillar near Salaulim Dam. The detail information is given in **section 5**.

Topographical Survey with Real time kinematic (RTK) technique is used for topographic survey and spot level. Section 6 covers topographical survey. Section 7 describes the processing of topographical survey data. Hydrographic survey is done using single beam eco sounder. Detail information is given in section 8. Methodology of survey is also covered in **section 8**. Location of water and soil samples is given in **section 9**. Section 10 to section 12 describes instruments used in the survey and their calibration.

Sub-section (I) of section 13 covers detail analysis of area elevation volume. It is done as per IS code 5477-Part-II, 1994.As per the sedimentation survey of 1984, original allocated capacity i.e., gross storage is 234.36 MCM up to elevation of 41.15 m i.e., FRL. Survey done in 2021 shows capacity is 208.823 MCM at elevation of 41.15 m.It is observed that loss of total storage i.e., deposition/accumulation of sediment in 37 years is 25.537 MCM upto FRL.At 43 m capacity is 308 MCM and 253 MCM in 1984 and 2021, respectively. Total deposition upto 43 m is 55 MCM. But upto FRL i.e., 41.15 m is 25.537 MCM. Between 41.15 m and 43 m deposition is (55-25.537) = 29.463 MCM. This value is too high and unrealistic as water is normally maintained at FRL and reaches 43 m only when remarkably high discharge enters. This may happen due sudden landslide. A comparison of reservoir capacity between year 1984 and 2021 are presented in Figure 0-1.
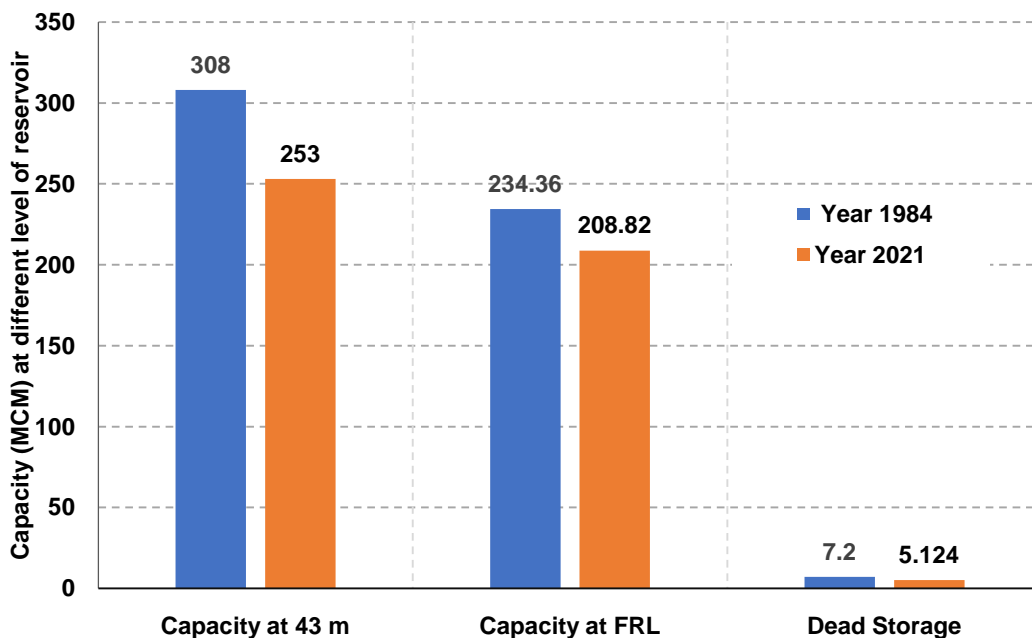

Figure 0-1   Comparison of reservoir capacity between year 1984 and 2021

Sub-section (II) shows the Mathematical modeling studies and output in form of new zero elevation, elevation-area-volume for 100 years at 10 years interval. Sediments are deposited in reservoirs at all elevations, causing the stage-capacity

curve to shift. Empirical methods have been developed to distribute sediment deposits within a reservoir as a function of depth, thereby projecting the shift in the stage-storage curve. There is different method to predict distribution of sediment in the reservoir. The method is Area-reduction method. It is mentioned in IS 5477 Part II 1994 "Fixing Capacities of Reservoirs – Dead Storage". Moody's Method is used to determine the new zero elevation, directly without trial-and-error process. Detailed analysis is given in Annexure II. **Error! Reference source not found.** shows Elevation-capacity for 10, 30, 50, 70 and 100 year for Salaulim Reservoir. New zero elevation at every 10 year is given in **Error! Reference source not found..**
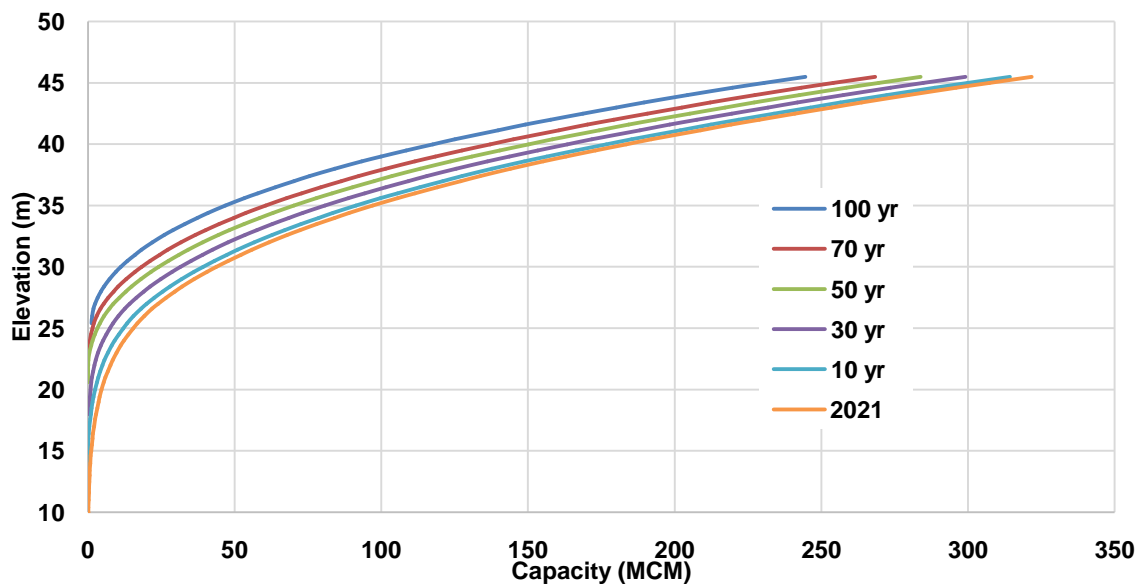

Figure 0-2   Elevation-capacity curve for different year for Salaulim Reservoir

Table 0-1   New zero elevation at every 10 year

Year	New Zero Elevation (m)	Year	New Zero Elevation (m)
10 yr	12.5	60 yr	22
20 yr	16	70 yr	22.4
30 yr	18	80 yr	23.6
40 yr	19.4	90 yr	24.5
50 yr	20.6	100 yr	25.4

It is observed from the study that capacity of reservoir at FRL is reduced from 208.49 MCM to 139.80 MCM in 100 years. Total reservoir capacity at every 10 year is depicted in Figure 0-3.
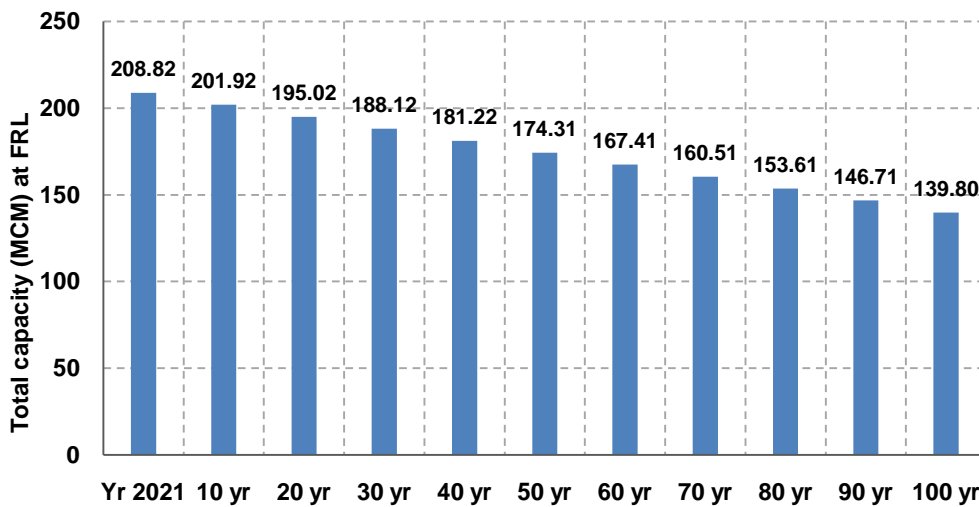
Figure 0-3   Comparison of reduced reservoir capacity at FRL (10-year interval)

Estimation of sedimentation in different zones of reservoir has been analyzed in **Sub-section (III)**. **Section (IV)** gives analysis of bed material samples, plan map showing the deposition of different type of sediments. **Sub-section (V)** covers cross-section drawings at different location of reservoir. Longitudinal sections are shown in **Sub-section (VI)** of section 13 in the report. **Sub-section (VII)** describes vertical sediment distribution based on IS code 5477-Part-II, 1994. Contour map and corresponding area calculations are done and given in **Sub-section (VIII).**

Trap efficiency of reservoir is also estimated for the reservoir. IS 12182 – 1987 1987"Guidelines for Determination of Effects of Sedimentation in Planning and Performance of Reservoirs", is used for finding trap efficiency. **Sub-section (IX)** deals with trap efficiency. Brune curve is used to estimate trap efficiency. Trap efficiency for Salaulim Dam corresponding C/I of 0.9 considering normally ponded reservoir is 97.2%. **Sub-section (X)** deals with Charts like Topographical map, Grid map etc.

Conclusions are drawn and recommendations are given in **Sub-section (XI)**. The conclusion drawn from this study is given below:

- Volume of sediment deposition is determined from 1984 and 2021 survey. It is observed that loss of total storage i.e., deposition/accumulation of sediment in 37 years is 25.537 MCM upto FRL. Deposition of sediment per year is 0.69 MCM/year. Capacity at MWL 45.5 m is not available in 1984. At 43 m capacity is 308 MCM and 253 MCM in 1984 and 2021, respectively. Total deposition upto 43 m is 55 MCM. But upto FRL i.e., 41.15 m is 25.537 MCM. Between 41.15 m and 43 m deposition is (55-25.537) = 29.463 MCM. This value is too high and unrealistic as water is normally maintained at FRL and reaches 43 m only when very high discharge enters. This may happen due sudden landslide.

- Total deposition of sediment per year is 0.69 MCM/year upto FRL (41.15 m).Catchment area = 209.04 km^2 Sediment yield = 3.3 $mm/km^2/yr$. Total deposition of sediment per year is 1.48 MCM/year considering sediment deposition upto 43 m. catchment area = 209.04 km^2, Sediment yield = 7.08 $mm/km^2/yr$

- Trap efficiency for Salaulim Dam corresponding to capacity: inflow ratio (C/I) of 0.9 considering normally ponded reservoir is 97.2%.

- According to IS 12182 – 1987 1987"Guidelines for Determination of Effects of Sedimentation in Planning and Performance of Reservoirs" 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. For Salaulim Dam upto FRL capacity is 208.823 MCM, Sediment deposition per year = 0.69 MCM upto FRL, average annual volume of sediment deposition with the gross capacity of the reservoir = 0.69/208.823 = 0.33% which is between 0.1% and 0.5%. The sediment problem is significant. For Salaulim Dam taking sediment deposition upto 43 m capacity is 253 MCM. Sediment deposition per year = 1.48 MCM upto 43 m. Average annual volume of sediment deposition with the gross capacity of the reservoir = 1.48/253 = 0.58% which is greater than 0.5%. The sediment problem is serious.

- It is observed that dead storage will be depleted within 50 years from 2021 and new zero elevation will be above dead storage level.

- 16.5% of live storage will be depleted within 50 years from 2021.

- 23% of live storage will be depleted within 70 years from 2021.

- 33% of live storage will be depleted within 100 years from 2021.

- New zero elevation after 50 year and 100 year will be 20.6 m and 25.4 m respectively.

Following recommendations are given:

- Cause of high deposition of sediment in Salulim dam between FRL and MWL may be investigated further. In Salulim catchment lots of mining activity occurs which may cause landslide and such deposition of sediment. Sediment samples may further to be analyzed from this zone to find out type of sediment and cause of such deposition to avoid flooding problem in future due to reduction of flood storage.

- The loss of storage will have an impact on storage of water. Simulation studies need to be done to assess water demands with desired reliability will be fulfilled in future.

- Suspended sediment data need to be collected each year for monsoon period to understand the sediment inflow coming each year during monsoon.

- As a common practice, sediment management can be done either by flushing or sluicing. Flushing can be done if enough water is available. Otherwise sluicing with maintaining low water level during peak flood can be option. There is no sluice available, and flushing is also a problem for this dam.

- In such cases it is recommended to find the source of sediment from the catchment and a detailed study need to be done for catchment area treatment plan. Salulim reservoirs catchment is highly affected with mining activities. In such cases it may not be viable to prepare an effective catchment treatment plan and implementation of the same.

- Dredging could be another option for sediment management. It may be an effective solution of sediment management provided it is cost effective and if an eco-friendly deposition site is identified in the vicinity of the reservoirs. It is recommended to do a separate study to find out efficacy of dredging considering cost and eco-friendly deposition site.

Limitations on sediment study are given in Sub-section (XI). Sediments are deposited in reservoirs at all elevations, causing the stage-capacity curve to shift. Empirical methods have been developed to distribute sediment deposits within a reservoir as a function of depth, thereby projecting the shift in the stage-storage curve. These methods are much quicker and easier to use than mathematical modeling and also require less data. When sediment survey data are available for an existing reservoir, the observed deposition pattern can be used to select the proper empirical relationship to compute the future shift in the stage-area and stage-capacity relationships. As a limitation, empirical methods do not identify the specific locations in a reservoir which will be affected by sediment; they predict only the change in the stage-area and stage-capacity curves. A significant shift in the operating regime, such as implementation of sediment management, will affect the deposition pattern. Empirical methods cannot be user to simulate these effects, and the evaluation of management alternatives requires numerical modeling.

Table of Contents

List of Figure

List of Table

1. Introduction of Salaulim Dam:-

Salaulim dam is located on the Salaulim River, a tributary of the Zuari River in Goa, India, is an integral component of the Salaulim irrigation project which envisages benefits of irrigation and drinking water supply. The dam is a composite earth cum masonry dam of 42.5 meters (139.44 ft) height with a catchment area of 209.04 Sq.km (80.71 Sq. miles). It was initially planned to provide irrigation to an ultimate potential of 14,326 hectares (35,400 acres) and water supply of 160 million liters per day (MLD) to south Goa; the water supply component for domestic and industrial use is now increased to 380 MLD. However the construction of the project was started in 1976 and the dam was completed in 2000.
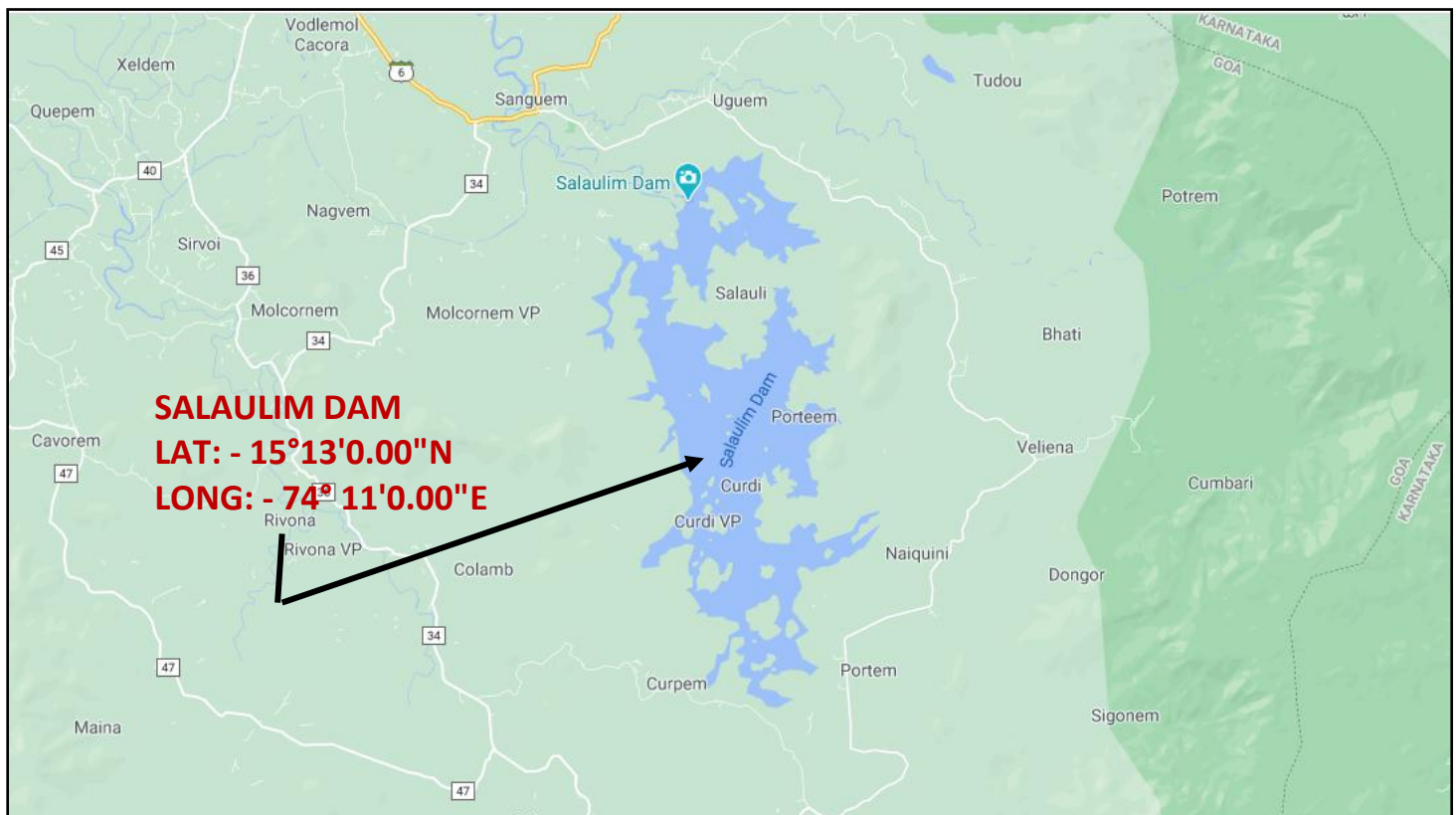
SALAULIM DAM
LAT: - 15°13'0.00"N
LONG: - 74° 11'0.00"E

1.1 Work Order:-

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

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

LETTER OF ACCEPTANCE
CUM NOTICE TO PROCEED WITH THE WORK

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

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

Sir,

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

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

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

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

Date of commencement of work: 02-03-2020

Date of Completion of work: 28-08-2020

Executive Engineer.
For and on behalf of Governor of Goa.

Copy submitted to: -
1 The Chief Engineer, WRD, Sinchai Bhavan, Porvorim-Goa.
2)The Superintending Engineer, Circle III/IV/V,WRD,GogalMargao-Goa.
3) Office Copy
4) Guard file.
Copy to: -
1) The Executive Engineer WD V/X WRD Sankali/Sanguem
1) The Assistant Engineer, SD III, WD III, WRD, Gogal-Margao Goa, to give the site location to the Contractor.
2) The Income Tax Officer, Panaji-Goa.
3) The Deputy Commercial Tax Officer, Ponda ward, Ponda-Goa
4) The Labour Commissioner, Junta House, Panaji-Goa

Figure 4- Work Order

1.2 Location:-

The Salaulim Dam lies on the Selaulim River at about 5 kms from Sanguem town. It is located at a distance of 37 kms from Margao and 70 kms from Panaji, the state capital.

The Dam is located at Sirga about 5 km from the Sanguem town. In the Zuari river basin, this is drained by Zuari River which in turn is formed after the confluence of Selaulim and Uguem rivers in Sanguem taluk. The latitude of the dam is 15°13'0.00"N and the longitude of the dam is 74°11'0.00"E.

Figure 5- Location Map of Salaulim Dam

1.2.1 Purpose:-

The primary purposes of Salaulim Dam are Irrigation and water supply and some of other important purposes.

1.3 Dam Description:-

The Dam is a composite structure of earth cum masonry type of 61.50 meters (201.77 ft.) height above the deepest foundation level and height of the lowest foundation level is 42.5 m (139.4 ft.). The length of dam at El. 46.025 m is 1003.83 meters (3,293.40 ft) and length of the masonry dam is 92.660 m (304 ft.). The Spillway which is of the unique Duckbill type (Morning glory type) is an ungated structure located in the gorge section with a length of 44 meters (144 ft). As a result, 220 MLD of water is available for industrial and domestic use in south Goa, in addition to 160 MLD originally provided in the approved project. The Dam has a Dead storage level 20.42 m., Live storage level is 20.42 m. to 41.15 m. The F.R.L of the dam is 41.148 m. and the M.W.L is up to the El.42.972 m.

1.4 Basin Description:-

The River drains a catchment area of 209.04 km2 (80.71 Sq. miles) upto the dam site. The spillway crest level is 35.052 m. and the maximum head over crest is 7.925 m. The length of the spillway is 24.384 m. and length of non overflow is 68.276m.

1.5 Hydrology:-

The Mean annual rainfall (Mons0on rainfall) is 3665 mm (144.3"). The Maximum design flood is 2883 cum/sec (1, 00,000 Cusec) and the maximum routed flood is 1450 cum/sec (51,200 Cusecs).

1.6 Reservoir Submergence:-

The Reservoir water spread at full reservoir level El. 41.15m is 29.64 Sq. km (2964 ha) (as per reports of the water Resources Department of Goa). The Reservoir submergence involved 20 villages which were partially or fully submerged. 3000 people were displaced and resettled. Mining areas were also submerged for which compensation was provided. The total storage capacity of the reservoir at FRL is 234.36 M.cum of which the effective (live) storage is 227.16 Mm3. The dead storage is 7.20 Mm3 at dead storage level.

2.0 Description about Sedimentation:-

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

2.1 Causes of Sedimentation in a Dam:-

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

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

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

Total Sediment deposited in the Dam

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Total Sediment Flowing in the River

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

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

2.2 Description about N.H.P:-

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

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

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

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

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

2.4 Weather:-

The survey was undertaken during the month of '20th January – 18th February, 2021'. The Temperatures became average for the Sedimentation Survey of Salaulim Dam.

3.0 Project Site Location Map of Salaulim Dam:-
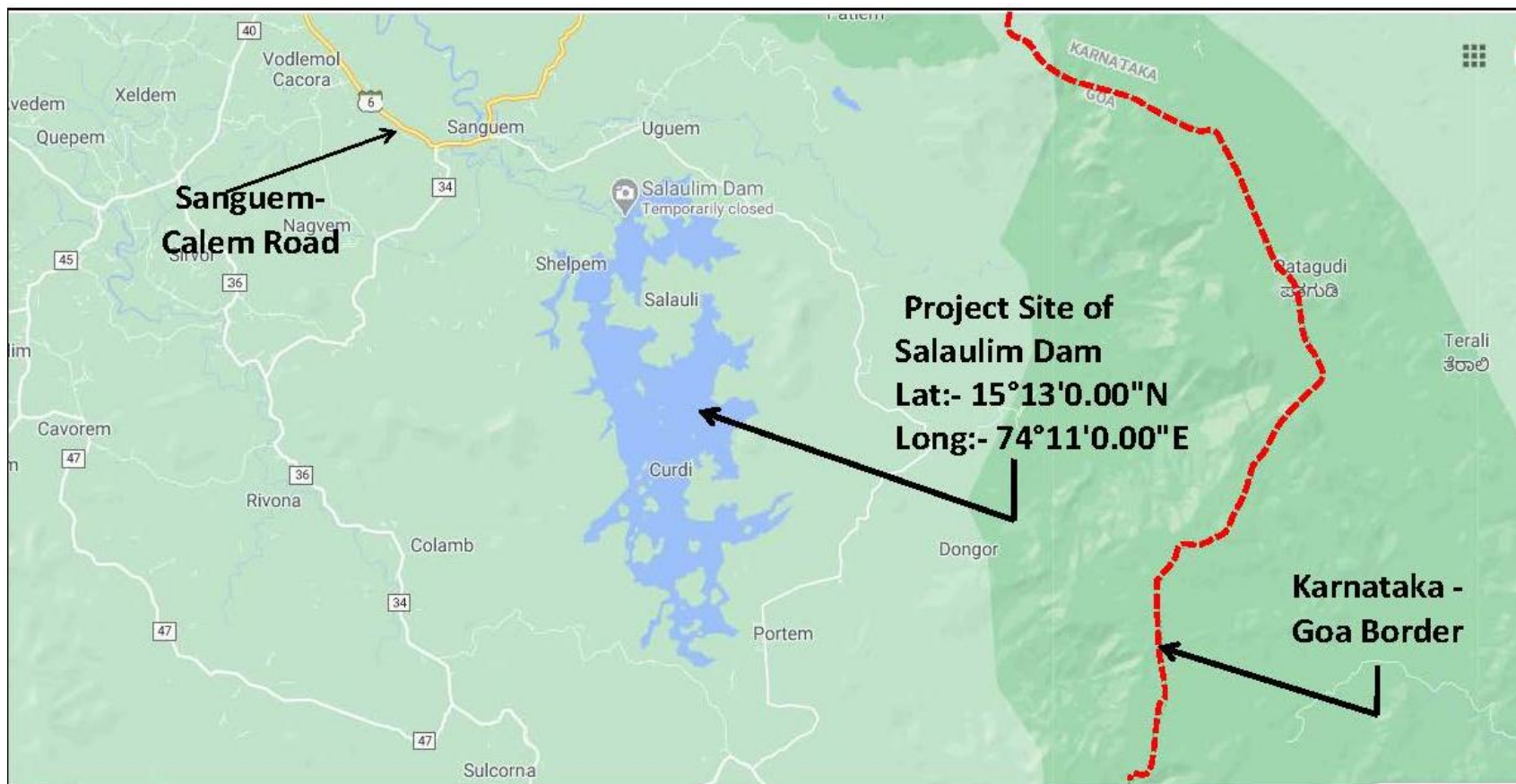
Figure 6-Project site location Map of Salaulim Dam
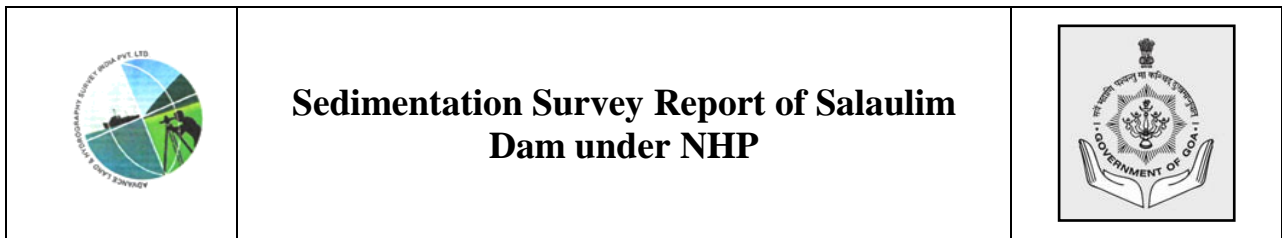
4.0 Scope of Work:-

The scope of the work includes:-

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

The Objective of Sedimentation survey is in the following:-

A. Request of Proposal:-

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

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

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

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

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

f. Analysis of data to obtain elevation-area-capacity table/curves, contour plots, balance life of 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 Dam, catchment characteristics, details of capacity survey performed including methodology of data collected, analysis of data with standard guidelines/Procedures, finding of results, conclusion and recommendations keeping in view the objective of the Water Resource department Goa.

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

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

B. Equipments Preferred :-

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

C. Capacity Survey:-

a) Hydrographic Survey

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

b) Topographic Survey

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

c) Collection of bed materials samples

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

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

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

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

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

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

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

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

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

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

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

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

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

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

viii) Contour map of the Dam

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

ix) Trap Efficiency of Dam

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

x) Charts/drawings for the Report

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

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

5.0 Authentic Reference level:-

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

Location	BM/CP	Easting (m)	Northing (m)	Latitude (N)	Longitude (E)	Elevation (m)
Salaulim Dam	GTS Pillar	411469.02	1681617.235	15°12'32.64"	74°10'32.63"	60.150

6.0 Conduct of survey work

6.1.1 Topography Survey with UAV system (Drone):-

The Island portions of the dam has surveyed by UAV or drone.

Instrument:-

LiDAR System:
Brand: SOUTH
Model: Z-Lab SZT-V100
Platform Optional: UAV

An unmanned aerial vehicle (UAV), commonly known as a drone, as an unmanned aircraft system (UAS), or by several other names, is an aircraft without a human pilot aboard. The flight of UAVs may operate with various degrees of autonomy; either under remote control by a human operator, or fly autonomously based on pre-programmed flight plans.

This instrument is ideal for carrying out Topographic Survey of any land where speed and accuracy is of priority, this UAV / Drone Survey data capture and processing to produce a ground accuracy upto 5 cm in horizontal and vertical.

At present we have shifted from the primitive method of DGPS & ETS (Electronic Total Stations) to the modern innovative method of DGPS, LiDAR and UAV/Drone for this project. Here, we establish control points by high precise Survey Grade Differential Global Positioning Systems in static mode, throughout the area to be surveyed. Then we capture 3D point cloud data using our LiDAR mapping system along the project site to be surveyed.

Thereafter, low altitude flying UAV/Drones used for capturing ground data with sufficient overlaps so as to develop a dense 3D point cloud data. This combined technology gives an accuracy of about +/- 5 cm globally, which is quite good as compared to the speed of Topographic survey. Contours can be generated at required intervals say 0.5 m or 1 m, using this dense 3D point cloud data and drawings are prepared upto the scale of 1:500 sufficient for planning and development of any infrastructure project.

Example of UAV-based Operation Time Sequence
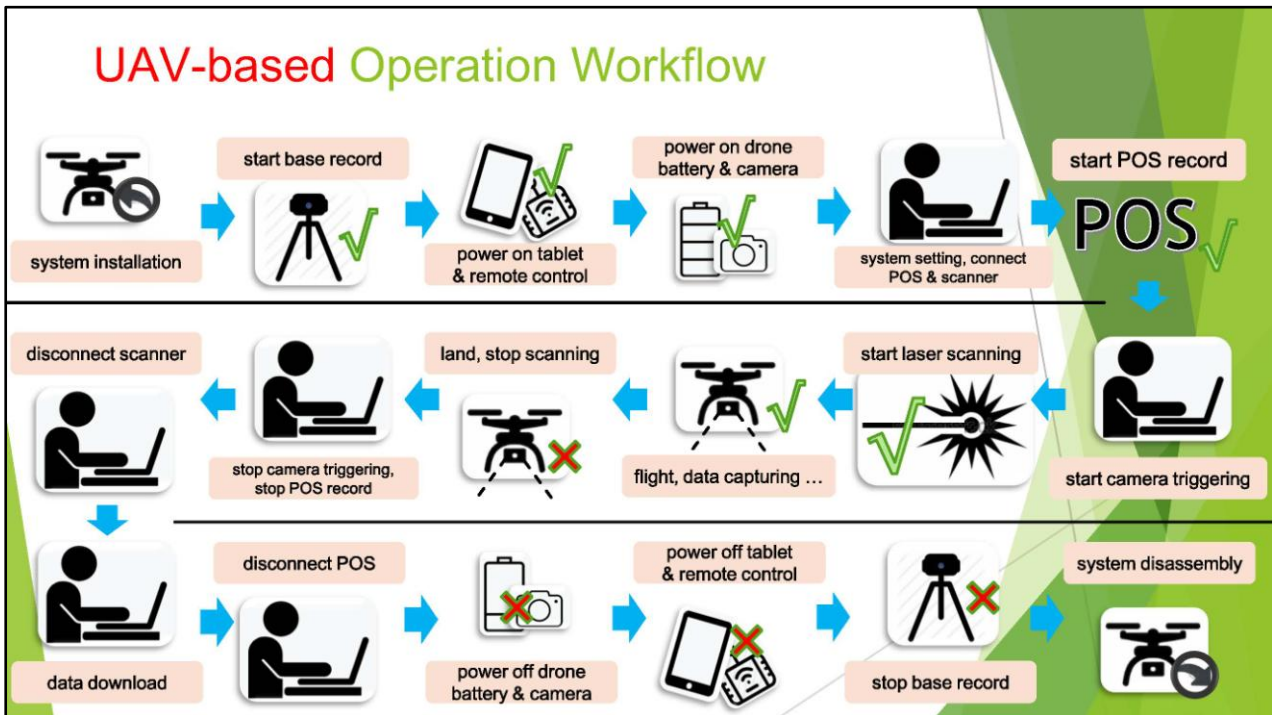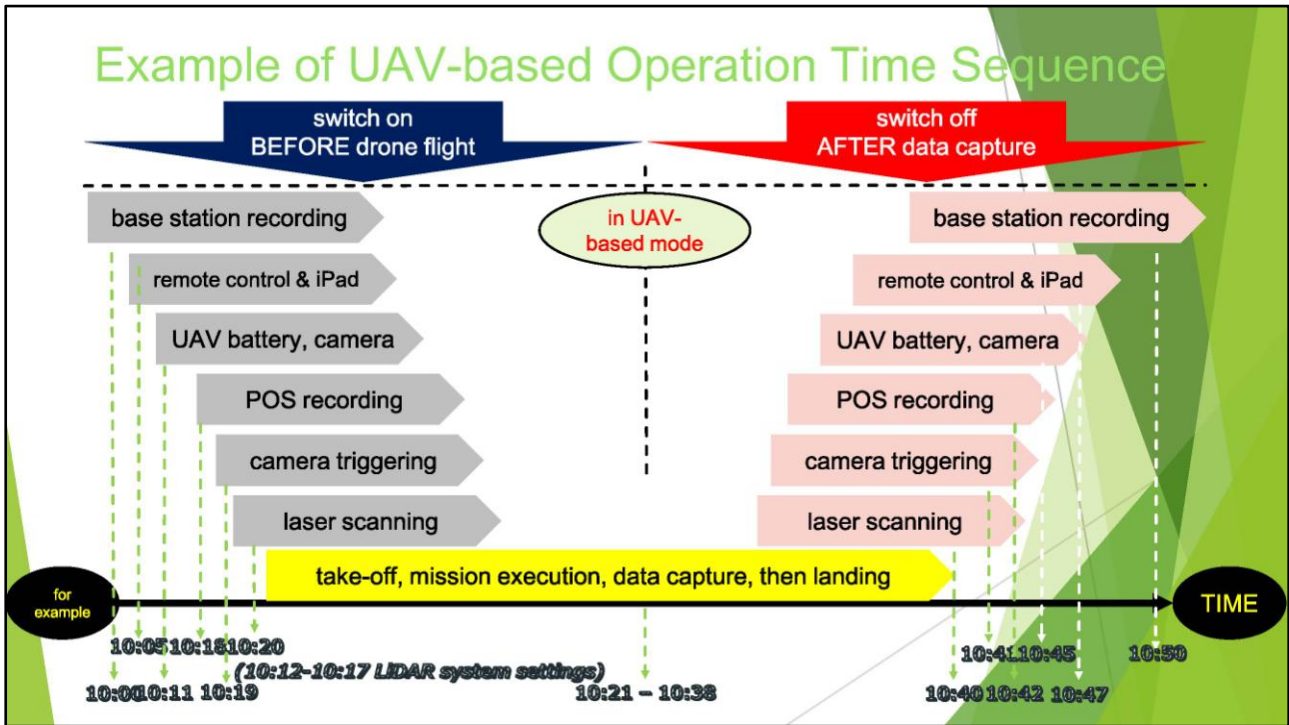
7.0 Data Processing:-

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:-
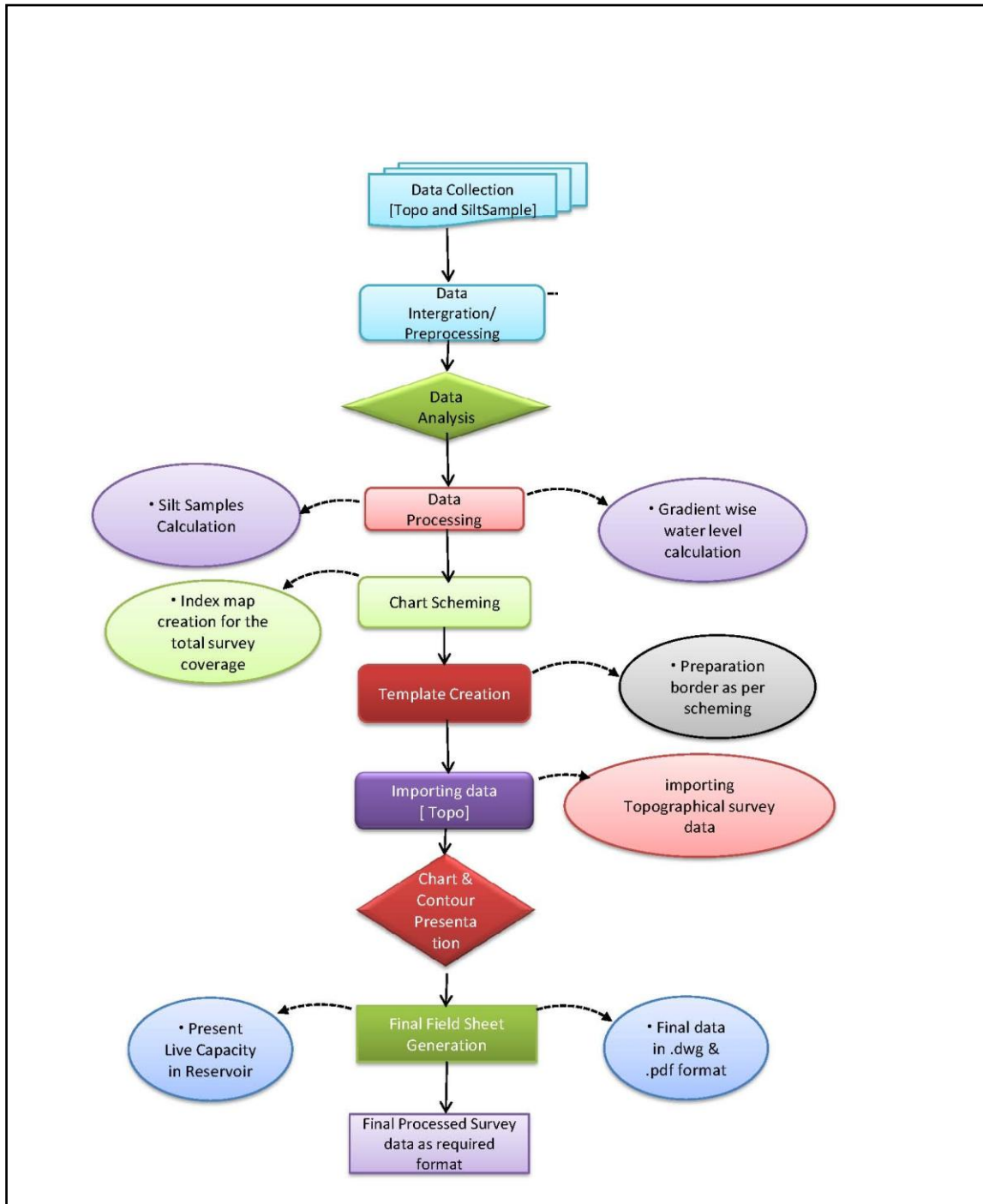
Table 2-Data Processing

8.0 Hydrography Survey with Echotrac-E-20:-

TELEDYNE ODOM HYDROGRAPHIC
SBES User Interface
Singlebeam Echosounders - Quick Start Guide

Operation Setup

- Select your desired operation mode.

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

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

Automatic	Full automated controls
Semi auto	Automated controls with available offsets for small adjustments
Manual	Set fixed values for the controls, adjust controls to your preference

Basics for Manual Mode

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

Control	Min	Max	Value	Unit
Power	166	219	219	dB
Gain	-178	178	0	dB
Pulse	22 µs	500 µs	31	µs
Pulse type		CW / Chirp		
Range	10	1000	18	Meter
Max ping rate	1	50	14	p/s
Current ping rate			13.55	p/s

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

Echogram Settings

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

Settings

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

TELEDYNE ODOM HYDROGRAPHIC

SBES User Interface
Singlebeam Echosounders - Quick Start Guide

TELEDYNE ODOM HYDROGRAPHIC
Everywhere**you**look™

Get Started

1. **Echosounder**
   - ☑ Get Started
   - ☑ Connect to Echosounder
   - ☐ Connect to Transducer

2. **Operation**
   - ☐ Open Operation menu
   - ☐ Select the Operation mode
   - ☐ Survey
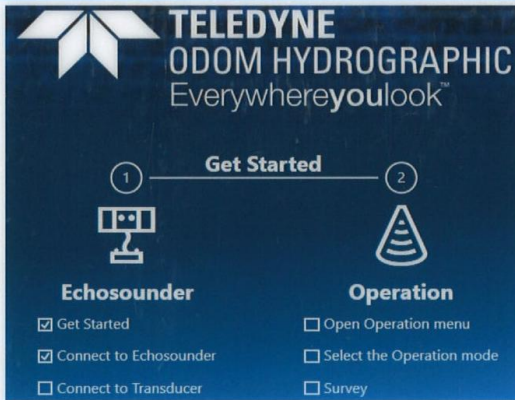
SBES User Interface

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

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

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

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

Echosounder Setup

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

Setup

Connect echosounder
10.11.10.1 : e20-3318004

Echosounder IP Address
10.11.10.1

Connect Transducer
Channel A	Channel B
None	Reson-TC2122-33kHz

Sound Velocity
1480 m/s

Draft
Channel A	Channel B
0 m	0 m

Units
| Meter | Feet |

Sensor Setup

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

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

Sensor

Position | Connect | Format
On | Serial port | NMEA GGA
Long: 013.28706 Lat: 058.29444

Motion | Connect | Format
On | Serial port | EM3000
H: 01.00 R: 00.18 P: -01.60

Output | Connect | Format
Off | Serial port |

8.1 Explanation Regarding the Methodology of Survey Work:-

1. Firstly we engaged a boat to survey the project site with equipped machineries.

2. We deployed Real Time Kinematics (RTK) with 20mm vertically & 10mm horizontally capability.

3. RTK had been shown the X & Y value.

4. In addition with this we engaged Echo-Sounder to calculate the depth. **Echotrac E-20** was used to obtain soundings on board the survey launches. A working frequency of 200 KHz was used for sounding operations. The digital output from the echo sounder was fed to the navigation data logging software for acquisition of survey data in real time. The performance of the echo sounder was found to be satisfactory during the entire duration of the survey.

5. We kept Power navigation software to interface RTK & ECHO Sounder.

6. Hypack navigation software helped to show the final date at the surveyed area.

7. Verification of water level in the Dam have constantly been monitored (manually from outside Dam) during hydrographic survey which have been used in operating Echo-sounder for measuring depth correctly.

8. Thus finally we got the result i.e. water level – depth.
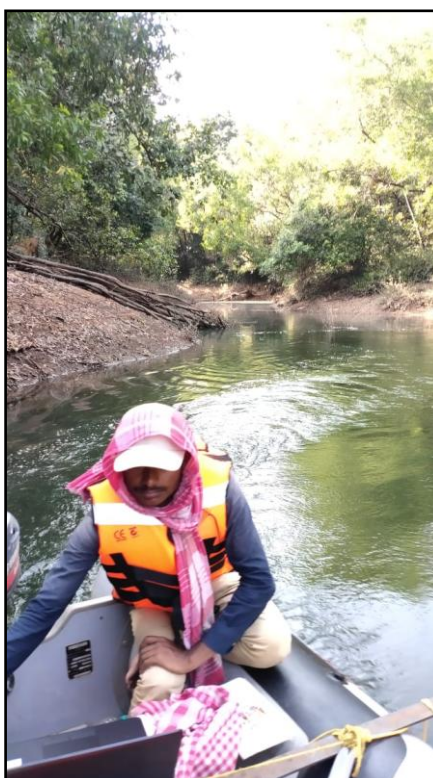
Figure 8 – During the Hydrography Survey in Salaulim Dam

8.2 Hydrography Survey Process :-
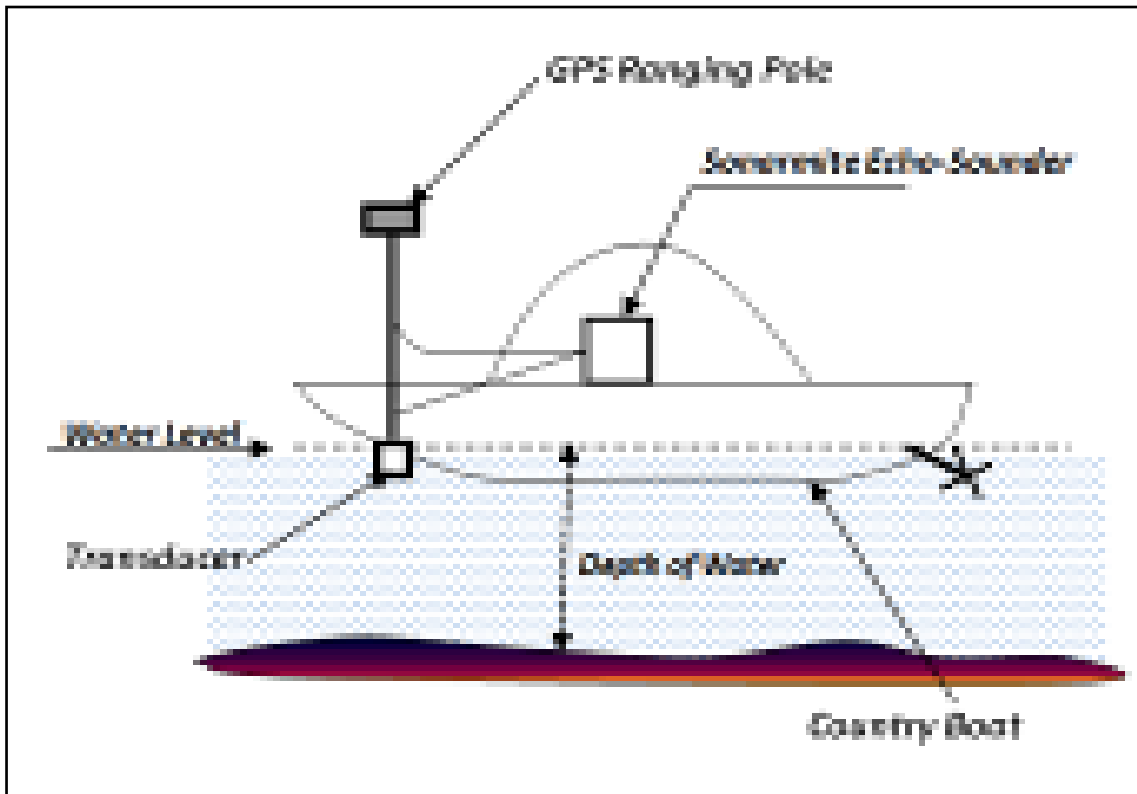
Figure 9 – Schematic diagram showing the sequence of operation

8.3 Hypack Data Processing System:-
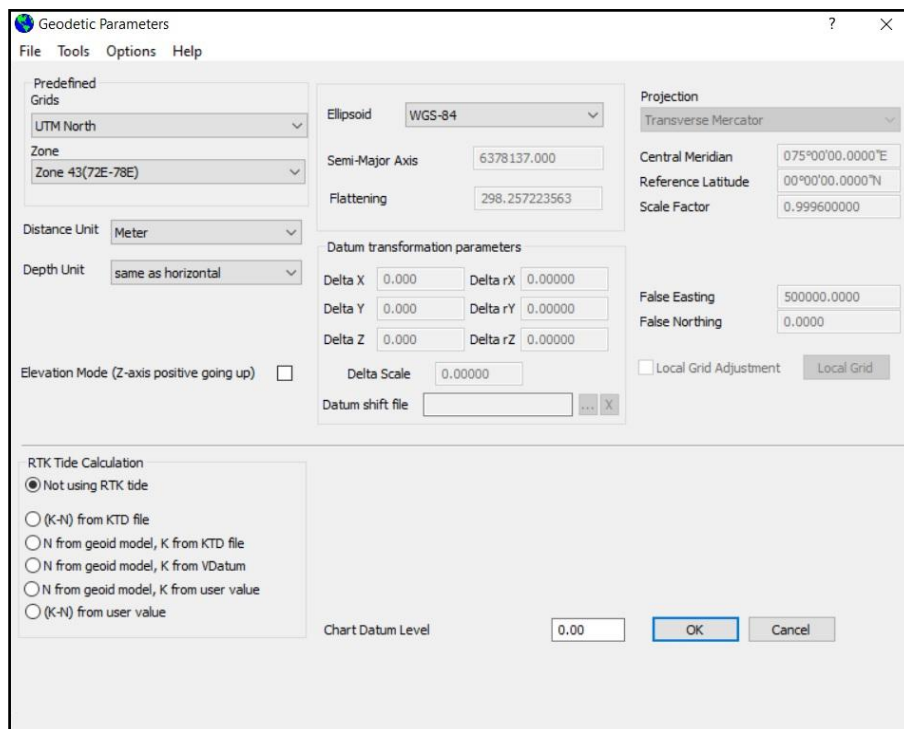
Figure 10-Hypack Data Logging, Geodetic Parameters
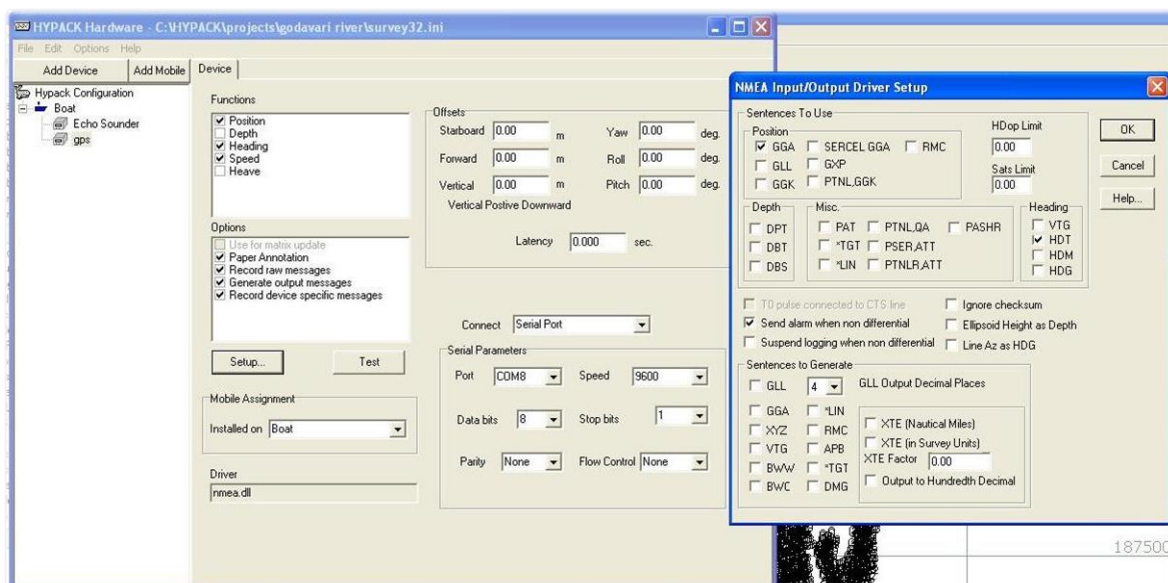
Figure 11 – Hypack Data logging, Navigation I/P settings
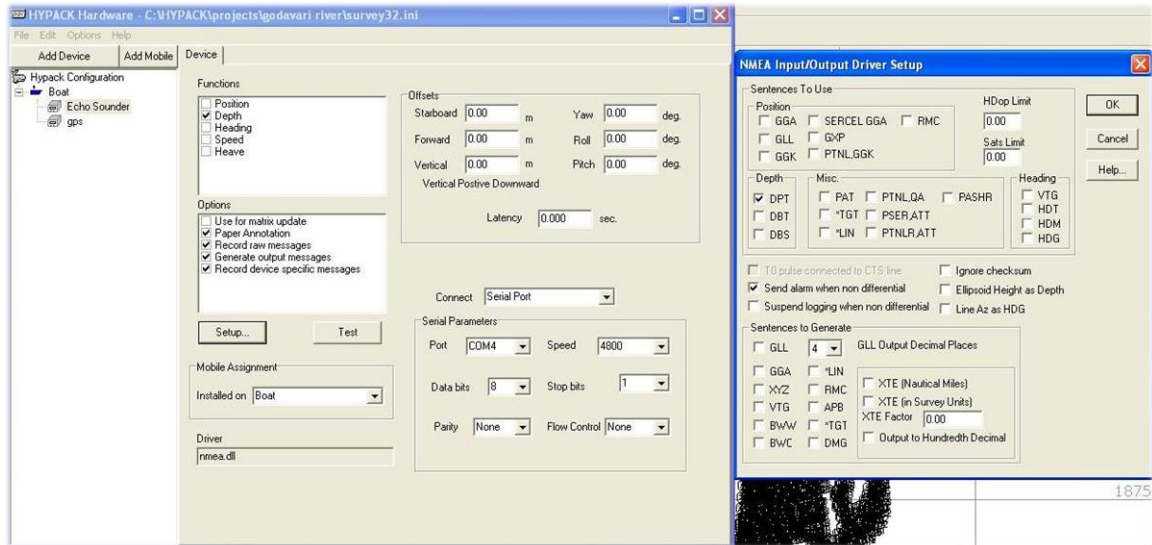
Figure 12 – Hypack Data Logging, Echo-sounder I/P settings
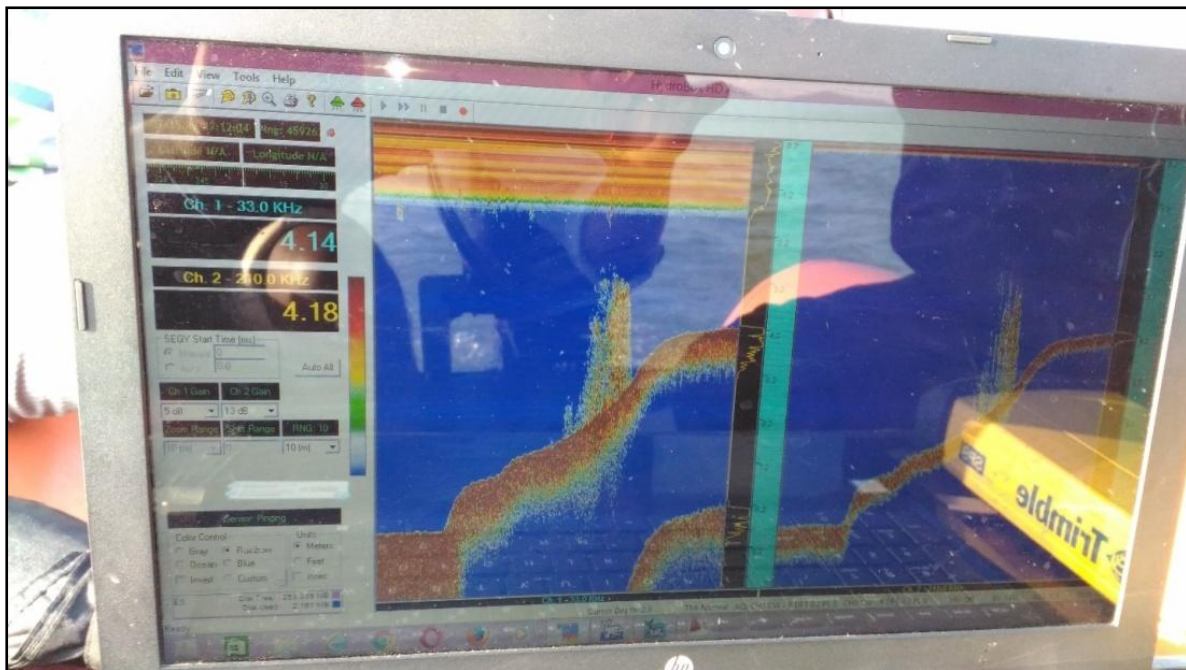
Figure 13-Hypack data processing

9.0 Soil & Water Sample Position:-

The Soil and water samples (15 no's) are collected from various locations near Salaulim Dam which are tabulated below. The location maps of soil samples are also indicate in the next pages (page no-31) with the same Coordinate.

Sl. No	Easting (m)	Northing (m)	Latitude (N)	Longitude (E)
1	411905.5	1682030	15°12'46.13"	74°10'47.21"
2	412801.4	1682568	15°13'3.74"	74°11'17.17"
3	413032.1	1681875	15°12'41.22"	74°11'24.99"
4	413575.6	1681193	15°12'19.10"	74°11'43.29"
5	412005.7	1680973	15°12'11.76"	74°10'50.70"
6	411190.6	1679259	15°11'15.87"	74°10'23.60"
7	413487.3	1678689	15°10'57.62"	74°11'40.64"
8	412164.6	1677685	15°10'24.75"	74°10'56.44"
9	413820.4	1677059	15°10'4.59"	74°11'52.00"
10	412654	1676537	15° 9'47.46"	74°11'12.98"
11	412909.7	1674994	15° 8'57.27"	74°11'21.74"
12	414779.4	1675144	15° 9'2.34"	74°12'24.36"
13	412248.8	1674001	15° 8'24.88"	74°10'59.72"
14	413505.5	1673234	15° 8'0.06"	74°11'41.92"
15	413515.8	1672303	15° 7'29.74"	74°11'42.35"

Table 3 – Soil & Water sample positions

9.1 Google image of Soil Sample locations:-

Figure 14-Soil sample locations

10.0 Salient Features of Salaulim Dam:-

Salient Features of Salaulim Dam	
Type of Dam	Composite dam (Multipurpose)
Location	Lat.-15°13'-N, Long.-74°11'-E
Length of Dam	1003.83 M
Height of Dam	42.50 M
Name of River	Guleli Nadi (Salaulimm)
Crest Level	R.L – 41.15 M
Deepest Bed Level	R.L – 4.75 M
Type of Spillway	Ungated Duckbill Spillway
Length ofSpillway	73.80 M
Full Reservoir Level	R.L – 41.15 M
Top of Dam	R.L – 47.65 M
Minimum draw down level	R.L – 47.65 M
Capacity at F.R.L	R.L – 20.42 M
Submergence area at F.R.L	234.36 MM^3
Catchment area	209.00 Sq. Km
Rehabilitation	Valkinim and Vaddem
Water Usage	Irrigation -144.66 MM^3 Water Supply- 82.50 MM^3
Length of Canal	Left bank main canal – 25.42 km
Command area	9686 HA
Submerged Villages Families and affected families	9 no's of villages displacing 643 Families

Table 4- Salient features of Salaulim Dam

11.0 Survey Equipments:-

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

Table 5- Details of equipment lists

o   Survey Boat/Vessel:- 1 no Survey Vessel with Yahama 9.9 stroke Engine:-

Figure 15- DGPS Survey Instrument

o   Positioning System:-

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

o   Navigation & Data Logging System:-

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

o   Single Beam Echo Sounder System:-

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

Figure 16- Echo Sounder Instrument (Echotrac E-20)

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

o   1 no. Soil Sampler (Van Veen Grab) & 1 no. Water (Bottle Sampler):-
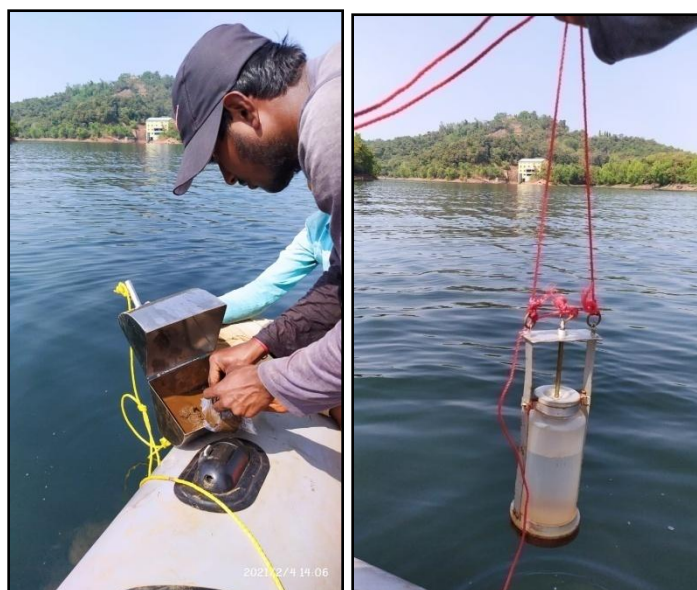
12. Calibration:-

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

12.1 Echo-Sounder Calibration:-

Figure 17- Calibration Certificate of Echo-Sounder (Echotrac E-20)

12.2 Trimble SPS-986:-

Figure 18- Calibration Certificate of SPS-986
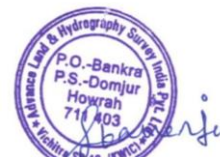
12.3 Calibration Certificate of SP-60 (Beacon Receiver):-

PAN INDIA CONSULTANTS PVT. LTD.

SALES DEPARTMENT

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

CALIBRATION CERTIFICATE

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

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

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

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 19-Calibration Certificate of SP-60
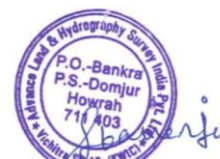
DATA ANALYSIS/PREPARATION OF TABLES/CHARTS/DRAWINGS
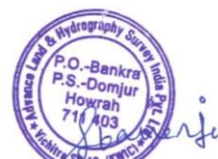
ELEVATION AREA CAPACITY CURVE AS WELL AS TABLE (i)

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

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

13.1 Elevation Area Capacity curves as well as table in the year 2021:-

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)

			Salaulim Reservoir_ Detail Analysis for Elevation And Area Capacity Table 2021			
SL. NO.	Contour EL (m)	Contour Interval (m)	Area		Capacity	
			in Sqm.	In Hectare	Vol. between two consecutive contour surface (in Cum.)	Cumulative Vol. (in M-Cum.)
1	-0.1	0.0	0.554	0.000	0.000	0.000
2	0.0	0.1	1.582	0.000	0.107	0.000
3	0.2	0.2	5.221	0.001	0.680	0.000
4	0.5	0.3	14.633	0.001	2.978	0.000
5	0.8	0.3	28.793	0.003	6.514	0.000
6	1.0	0.2	40.864	0.004	6.966	0.000
7	1.1	0.1	47.695	0.005	4.428	0.000
8	1.4	0.3	71.347	0.007	17.856	0.000
9	1.7	0.3	99.740	0.010	25.663	0.000
10	2.0	0.3	368.189	0.037	70.189	0.000
11	2.3	0.3	511.936	0.051	132.019	0.000
12	2.6	0.3	663.103	0.066	176.256	0.000
13	2.9	0.3	822.406	0.082	222.826	0.001
14	3.0	0.1	877.312	0.088	84.986	0.001
15	3.2	0.2	1007.898	0.101	188.521	0.001

			Area		Capacity	
SL. NO.	Contour EL (m)	Contour Interval (m)	in Sqm.	In Hectare	Vol. between two consecutive contour surface (in Cum.)	Cumulative Vol. (in M-Cum.)
16	3.5	0.3	1271.527	0.127	341.914	0.001
17	3.8	0.3	1594.491	0.159	429.903	0.002
18	4.0	0.2	1830.707	0.183	342.520	0.002
19	4.1	0.1	1963.898	0.196	189.730	0.002
20	4.4	0.3	2431.006	0.243	659.236	0.003
21	4.7	0.3	2878.993	0.288	796.500	0.004
22	5.0	0.3	3340.995	0.334	932.998	0.005
23	5.3	0.3	3891.190	0.389	1084.828	0.006
24	5.6	0.3	4541.145	0.454	1264.850	0.007
25	5.9	0.3	5295.660	0.530	1475.521	0.008
26	6.0	0.1	5570.754	0.557	543.321	0.009
27	6.2	0.2	6144.206	0.614	1171.496	0.010
28	6.5	0.3	7064.291	0.706	1981.275	0.012
29	6.8	0.3	8306.388	0.831	2305.602	0.014
30	7.0	0.2	9301.933	0.930	1760.832	0.016
31	7.1	0.1	9849.934	0.985	957.593	0.017
32	7.4	0.3	11767.860	1.177	3242.669	0.020
33	7.7	0.3	14402.040	1.440	3925.485	0.024
34	8.0	0.3	18994.220	1.899	5009.439	0.029
35	8.3	0.3	24217.485	2.422	6481.756	0.036
36	8.6	0.3	29715.625	2.972	8089.966	0.044
37	8.9	0.3	36415.471	3.642	9919.664	0.054
38	9.0	0.1	38907.897	3.891	3766.168	0.058
39	9.2	0.2	43959.900	4.396	8286.780	0.066
40	9.5	0.3	51942.901	5.194	14385.420	0.080
41	9.8	0.3	60249.224	6.025	16828.819	0.097
42	10.0	0.2	66056.921	6.606	12630.615	0.110
43	10.1	0.1	68880.761	6.888	6746.884	0.116

			Area		Capacity	
SL. NO.	**Contour EL (m)**	**Contour Interval (m)**	**Area**		**Capacity**	
			in Sqm.	*In Hectare*	*Vol. between two consecutive contour surface (in Cum.)*	*Cumulative Vol. (in M-Cum.)*
44	10.4	0.3	77951.045	7.795	22024.771	0.139
45	10.7	0.3	88596.717	8.860	24982.164	0.163
46	11.0	0.3	100697.920	10.070	28394.196	0.192
47	11.3	0.3	113465.909	11.347	32124.574	0.224
48	11.6	0.3	126443.608	12.644	35986.428	0.260
49	11.9	0.3	140124.702	14.012	39985.247	0.300
50	12.0	0.1	145114.693	14.511	14261.970	0.314
51	12.2	0.2	155626.881	15.563	30074.157	0.344
52	12.5	0.3	172611.821	17.261	49235.805	0.394
53	12.8	0.3	191043.786	19.104	54548.341	0.448
54	13.0	0.2	204483.312	20.448	39552.710	0.488
55	13.1	0.1	211310.778	21.131	20789.704	0.508
56	13.4	0.3	233099.809	23.310	66661.588	0.575
57	13.7	0.3	256142.064	25.614	73386.281	0.648
58	14.0	0.3	278602.359	27.860	80211.663	0.729
59	14.3	0.3	302295.012	30.230	87134.606	0.816
60	14.6	0.3	329186.798	32.919	94722.271	0.911
61	14.9	0.3	358488.076	35.849	103151.231	1.014
62	15.0	0.1	368296.753	36.830	36339.241	1.050
63	15.2	0.2	388478.033	38.848	75677.479	1.126
64	15.5	0.3	420202.944	42.020	121302.147	1.247
65	15.8	0.3	452995.402	45.300	130979.752	1.378
66	16.0	0.2	477014.143	47.701	93000.954	1.471
67	16.1	0.1	489259.378	48.926	48313.676	1.519
68	16.4	0.3	526713.331	52.671	152395.906	1.672
69	16.7	0.3	566252.441	56.625	163944.866	1.836
70	17.0	0.3	609418.830	60.942	176350.691	2.012
71	17.3	0.3	653898.020	65.390	189497.528	2.202
72	17.6	0.3	700020.409	70.002	203087.764	2.405
73	17.9	0.3	750106.392	75.011	217519.020	2.622
74	18.0	0.1	767050.631	76.705	75857.851	2.698
75	18.2	0.2	801444.800	80.144	156849.543	2.855
76	18.5	0.3	854601.561	85.460	248406.954	3.103
77	18.8	0.3	910342.343	91.034	264741.586	3.368
78	19.0	0.2	948530.707	94.853	185887.305	3.554

			Area		Capacity	
SL. NO.	**Contour EL (m)**	**Contour Interval (m)**	**in Sqm.**	**In Hectare**	**Vol. between two consecutive contour surface (in Cum.)**	**Cumulative Vol. (in M-Cum.)**

Salaulim Reservoir_ Detail Analysis for Elevation And Area Capacity Table 2021

SL. NO.	Contour EL (m)	Contour Interval (m)	in Sqm.	In Hectare	Vol. between two consecutive contour surface (in Cum.)	Cumulative Vol. (in M-Cum.)
79	19.1	0.1	969212.550	96.921	95887.163	3.650
80	19.4	0.3	1029365.059	102.937	299786.641	3.950
81	19.7	0.3	1096678.454	109.668	318906.527	4.268
82	20.0	0.3	1169869.829	116.987	339982.242	4.608
83	20.3	0.3	1250705.220	125.071	363086.257	4.972
84	**20.4**	**0.1**	**1287025.082**	**128.703**	**152263.818**	**5.124**
85	20.6	0.2	1342511.686	134.251	236658.309	5.360
86	20.9	0.3	1447161.668	144.716	418451.003	5.779
87	21.0	0.1	1483224.340	148.322	146519.300	5.925
88	21.2	0.2	1557228.453	155.723	304045.279	6.229
89	21.5	0.3	1667428.283	166.743	483698.510	6.713
90	21.8	0.3	1782711.137	178.271	517520.913	7.231
91	22.0	0.2	1861824.094	186.182	364453.523	7.595
92	22.1	0.1	1900252.203	190.025	188103.815	7.783
93	22.4	0.3	2019149.758	201.915	587910.294	8.371
94	22.7	0.3	2145170.407	214.517	624648.025	8.996
95	23.0	0.3	2286409.403	228.641	664736.972	9.661
96	23.3	0.3	2447725.244	244.773	710120.197	10.371
97	23.6	0.3	2619816.795	261.982	760131.306	11.131
98	23.9	0.3	2793102.129	279.310	811937.839	11.943
99	24.0	0.1	2854104.911	285.410	282360.352	12.225
100	24.2	0.2	2978352.608	297.835	583245.752	12.808
101	24.5	0.3	3166430.220	316.643	921717.424	13.730
102	24.8	0.3	3339051.939	333.905	975822.324	14.706
103	25.0	0.2	3450153.684	345.015	678920.562	15.385
104	25.1	0.1	3507279.481	350.728	347871.658	15.733
105	25.4	0.3	3688950.231	368.895	1079434.457	16.812
106	25.7	0.3	3898249.929	389.825	1138080.024	17.950
107	26.0	0.3	4145378.176	414.538	1206544.216	19.157
108	26.3	0.3	4488504.961	448.850	1295082.471	20.452
109	26.6	0.3	4816030.137	481.603	1395680.265	21.847
110	26.9	0.3	5107397.349	510.740	1488514.123	23.336
111	27.0	0.1	5205715.705	520.572	515655.653	23.852
112	27.2	0.2	5408508.020	540.851	1061422.373	24.913
113	27.5	0.3	5687173.645	568.717	1664352.250	26.577

			Area		Capacity	

SL. NO.	Contour EL (m)	Contour Interval (m)	in Sqm.	In Hectare	Vol. between two consecutive contour surface (in Cum.)	Cumulative Vol. (in M-Cum.)
114	27.8	0.3	5962488.673	596.249	1747449.348	28.325
115	28.0	0.2	6143346.951	614.335	1210583.562	29.535
116	28.1	0.1	6233428.948	623.343	618838.795	30.154
117	28.4	0.3	6513386.437	651.339	1912022.308	32.066
118	28.7	0.3	6785692.845	678.569	1994861.892	34.061
119	29.0	0.3	7058325.222	705.833	2076602.710	36.138
120	29.3	0.3	7344940.092	734.494	2160489.797	38.298
121	29.6	0.3	7625418.107	762.542	2245553.730	40.544
122	29.9	0.3	7915255.611	791.526	2331101.058	42.875
123	30.0	0.1	8011182.689	801.118	796321.915	43.671
124	30.2	0.2	8199335.715	819.934	1621051.840	45.292
125	30.5	0.3	8486287.041	848.629	2502843.413	47.795
126	30.8	0.3	8776452.153	877.645	2589410.879	50.385
127	31.0	0.2	8971455.799	897.146	1774790.795	52.159
128	31.1	0.1	9071723.301	907.172	902158.955	53.062
129	31.4	0.3	9381025.201	938.103	2767912.275	55.829
130	31.7	0.3	9692083.481	969.208	2860966.302	58.690
131	32.0	0.3	10010724.881	1001.072	2955421.254	61.646
132	32.3	0.3	10334686.398	1033.469	3051811.692	64.698
133	32.6	0.3	10674079.594	1067.408	3151314.899	67.849
134	32.9	0.3	11022121.261	1102.212	3254430.128	71.103
135	33.0	0.1	11139136.285	1113.914	1108062.877	72.211
136	33.2	0.2	11381595.427	1138.160	2252073.171	74.463
137	33.5	0.3	11761242.230	1176.124	3471425.649	77.935
138	33.8	0.3	12157625.137	1215.763	3587830.105	81.523
139	34.0	0.2	12417472.534	1241.747	2457509.767	83.980
140	34.1	0.1	12547927.664	1254.793	1248270.010	85.229
141	34.4	0.3	12935922.021	1293.592	3822577.453	89.051
142	34.7	0.3	13307453.795	1330.745	3936506.372	92.988
143	35.0	0.3	13689719.883	1368.972	4049576.052	97.037
144	35.3	0.3	14082569.611	1408.257	4165843.424	101.203
145	35.6	0.3	14477051.790	1447.705	4283943.210	105.487
146	35.9	0.3	14863904.629	1486.390	4401143.463	109.888
147	36.0	0.1	14991331.656	1499.133	1492761.814	111.381
148	36.2	0.2	15241391.048	1524.139	3023272.270	114.404

		Salaulim Reservoir_ Detail Analysis for Elevation And Area Capacity Table 2021				
SL. NO.	Contour EL (m)	Contour Interval (m)	Area		Capacity	
			in Sqm.	In Hectare	Vol. between two consecutive contour surface (in Cum.)	Cumulative Vol. (in M-Cum.)
149	36.5	0.3	15625982.701	1562.598	4630106.062	119.034
150	36.8	0.3	16024677.158	1602.468	4747598.979	123.782
151	37.0	0.2	16296590.149	1629.659	3232126.731	127.014
152	37.1	0.1	16437590.964	1643.759	1636709.056	128.651
153	37.4	0.3	16881007.589	1688.101	4997789.783	133.648
154	37.7	0.3	17364251.714	1736.425	5136788.895	138.785
155	38.0	0.3	17922056.439	1792.206	5292946.223	144.078
156	38.3	0.3	18491264.832	1849.126	5461998.191	149.540
157	38.6	0.3	18998487.895	1899.849	5623462.909	155.164
158	38.9	0.3	19498528.558	1949.853	5774552.468	160.938
159	39.0	0.1	19665892.617	1966.589	1958221.059	162.896
160	39.2	0.2	20012634.027	2001.263	3967852.664	166.864
161	39.5	0.3	20482162.052	2048.216	6074219.412	172.939
162	39.8	0.3	20946659.247	2094.666	6214323.195	179.153
163	40.0	0.2	21267260.353	2126.726	4221391.960	183.374
164	40.1	0.1	21536010.135	2153.601	2140163.524	185.514
165	40.4	0.3	21924561.876	2192.456	6519085.802	192.033
166	40.7	0.3	22291308.878	2229.131	6632380.613	198.666
167	41.0	0.3	22663583.921	2266.358	6743233.920	205.409
168	**41.15**	**0.15**	**22856028.903**	**2285.603**	**3413970.962**	**208.823**
169	41.3	0.1	23106622.653	2310.662	3447198.867	212.270
170	41.6	0.3	23530990.066	2353.099	6995641.908	219.266
171	41.9	0.3	23911628.271	2391.163	7116392.751	226.382
172	42.0	0.1	24036854.926	2403.685	2397424.160	228.780
173	42.2	0.2	24287258.854	2428.726	4832411.378	233.612
174	42.5	0.3	24668607.777	2466.861	7343379.995	240.956
175	42.8	0.3	25104852.545	2510.485	7466019.048	248.422
176	43.0	0.2	25367039.025	2536.704	5047189.157	253.469
177	43.1	0.1	25499175.406	2549.918	2543310.722	256.012
178	43.4	0.3	25900661.103	2590.066	7709975.476	263.722
179	43.7	0.3	26445023.158	2644.502	7851852.639	271.574
180	44.0	0.3	26888980.318	2688.898	8000100.521	279.574
181	44.3	0.3	27332784.937	2733.278	8133264.788	287.707
182	44.6	0.3	27835238.139	2783.524	8275203.461	295.982
183	44.9	0.3	28286596.054	2828.660	8418275.129	304.401

SL. NO.	Contour EL (m)	Contour Interval (m)	Area		Capacity	
			in Sqm.	In Hectare	Vol. between two consecutive contour surface (in Cum.)	Cumulative Vol. (in M-Cum.)
184	45.0	0.1	28436829.773	2843.683	2836171.291	307.237
185	45.2	0.2	28733096.563	2873.310	5716992.634	312.954
186	**45.5**	**0.3**	**29180595.337**	**2918.060**	**8687053.785**	**321.641**

Salaulim Reservoir_ Detail Analysis for Elevation And Area Capacity Table 2021

Table 6-Capacity area Table of Salaulim Dam in the year 2021

13.1.1 Area Capacity Curve in the year 2021:-
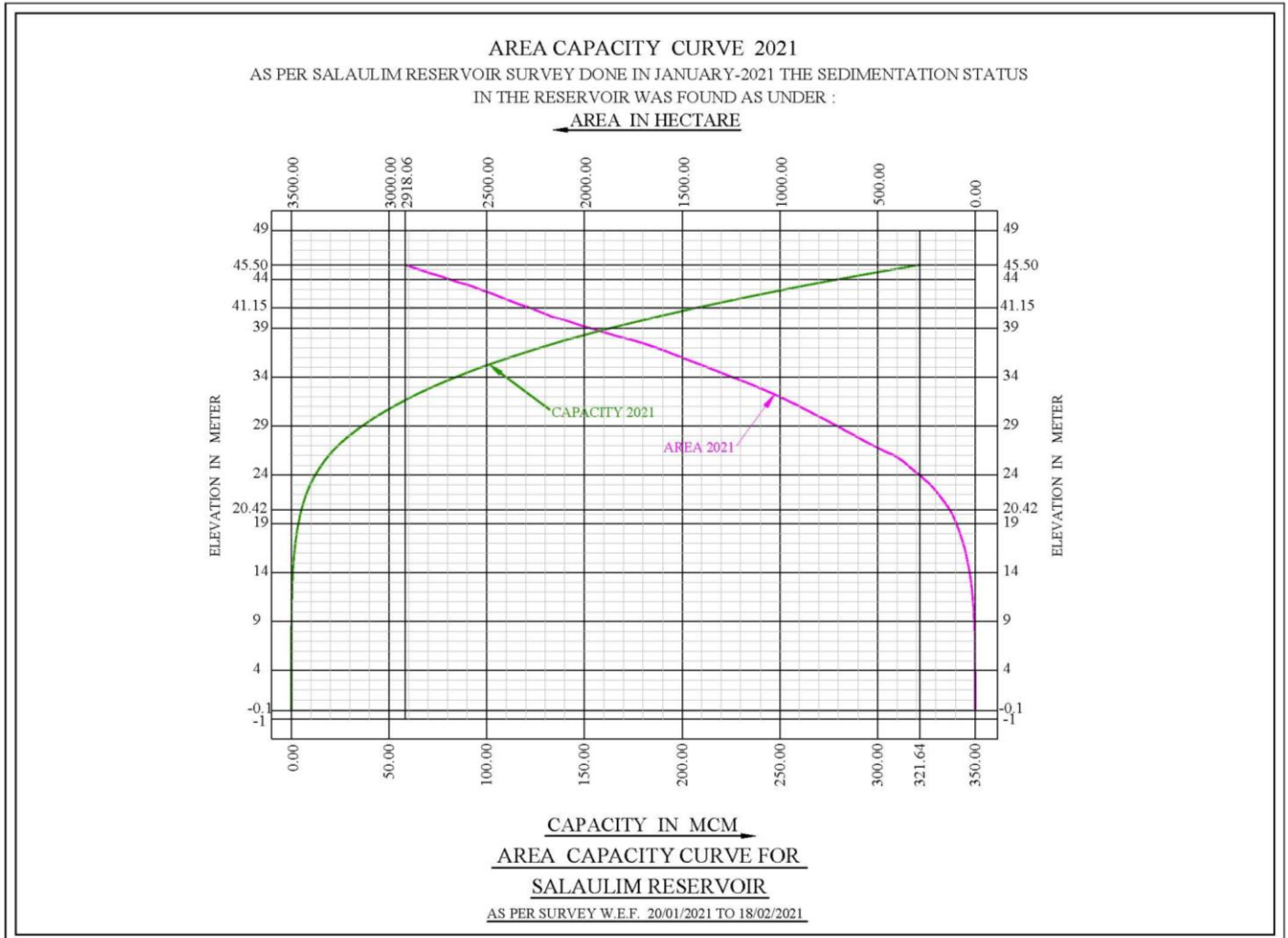
Figure 20-Area Capacity Curve in the year 2021

13.1.2 Area Capacity Curve in the year between 1984 & 2021:-
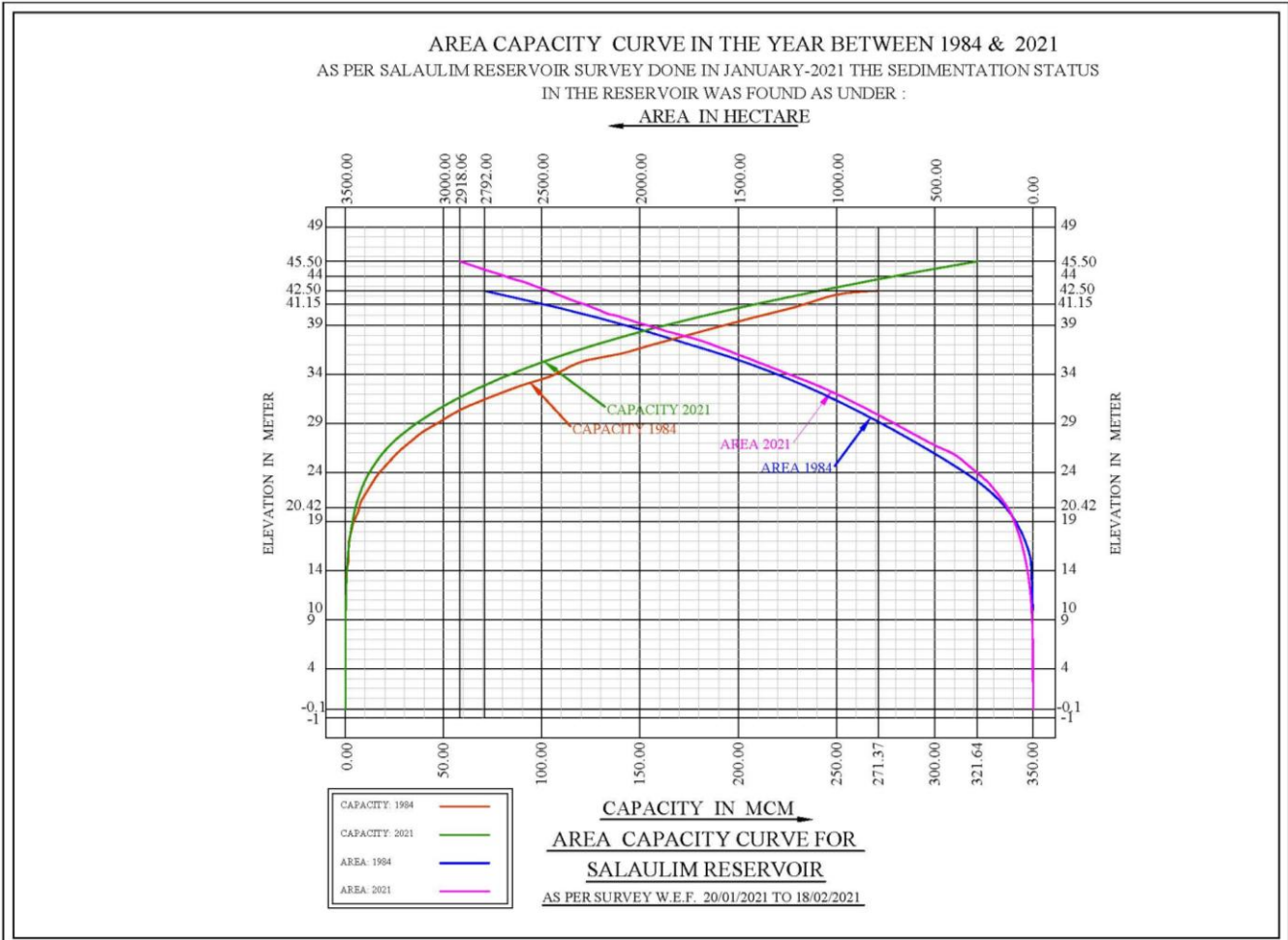
Figure 21-Area Capacity Curve in the year between 1984 & 2021

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

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

- **Original Allotted Capacity in the Year of 1984:-**

Original Capacity Survey:-

As per the sedimentation survey of 1984, original allocated capacity was computed of 189998.74 acre feet (234.360 MCM) up to elevation 135 ft (41.15 m.). Hence the total original allocated capacity was established in the year 1984 as 189998.74 acre feet (234.360 MCM).

Table-I

Storage level	El-From-To	Original Allocated Capacity (MCM)	Original Allocated Capacity (ACRE FT)
Dead Storage	(Upto El. 66.99 ft) (20.42 m)	7.20	5837.13
Live Storage	(El.66.99 – 135 ft (20.42 m – 41.15 m.)	227.16	184161.61
Total =		234.360	189998.74

- **CAPACITY OF SALAULIM DAM IN DIFFERENT SURVEY IN DIFFERENT ZONES:-**

Table-II

Capacity in Salaulim Dam in Different Years In Different zones			
(Capacity In ACRE FEET (MCM), Elevation in ft./m)			
ZONE	Dead storage	Live Storage	Overall
YEAR	El. 66.99 ft (20.42 m)	El.66.99 - 135 ft (20.42 – 41.15 m)	
1984	5837.13 (7.20)	184161.61 (227.16)	189998.74 (234.360)
2021	4154.09 (5.124)	165141.46 (203.70)	169295.55 (208.82)

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

1. Data Collection:-

For this study following data is required.
- Elevation-area-capacity survey at present year and original elevation-area-capacity survey to understand deposition of sediment volume.

- Annual inflow for 30 years or more

In this study sedimentation survey of 1984 i.e., original elevation-area-capacity and elevation-area-capacity survey in 2021 are received. No inflow data are received. Seven years of water demand data are received. These data are used to estimate inflow. Seven years of data may not be representative and may give over or underestimate of average annual inflow. It would have an impact on capacity to inflow ratio which may lead to impact on trap efficiency.

2. Capacity of reservoir and annual sediment deposition:-

A comparison of reservoir capacity between year 1984 and 2021 are presented in Figure 0-4. As per the sedimentation survey of 1984, original allocated capacity i.e., gross storage is234.36 MCM up to elevation of 41.15 m i.e., FRL. Survey done in 2021 shows capacity is 208.823 MCM at elevation of 41.15 m. Salient features of reservoir related to storage in 1984 and 2021 is given in Table 0-2. It is observed that loss of total storage i.e., deposition/accumulation of sediment in 37 years is 25.537 MCM upto FRL. Deposition of sediment per year is 0.69 MCM/year. Capacity at MWL 45.5 m is not available in 1984. At 43 m capacity is 308 MCM and 253 MCM in 1984 and 2021, respectively. Total deposition upto 43 m is 55 MCM. But upto FRL i.e., 41.15 m is 25.537 MCM. Between 41.15 m and 43 m deposition is (55-25.537) = 29.463 MCM. This value is too high and unrealistic as water is normally maintained at FRL and reaches 43 m only when very high discharge enters. This may happen due sudden landslide. Therefore, trial and error process are done to make sure deposition rate at FRL is 0.69 MCM/year. It is observed that reduction in Capacity 7.2 MCM to 5.124 MCM in dead storage.

Figure 0-1   Comparison of reservoir capacity between year 1984 and 2021

Table 0-1   Salient features of Salaulim reservoir related to storage in 1984 and 2021

FRL	41.15 m
Dead storage level	20.4 m
Capacity at FRL in 1984	234.36 MCM
Capacity at DSL in 1984	7.2 MCM
Capacity at FRL in 2021	208.823 MCM
Capacity at DSL in 2021	5.124 MCM
Live storage in 1984	227.16 MCM
Dead storage in 1984	7.2 MCM
Live storage in 2021	203.70 MCM
Dead storage in 2021	5.124 MCM

Catchment area of Salaulim Dam is 209.04 km^2. Annual sediment deposition is 0.69 MCM/year upto FRL. Sediment yield becomes 3.3 mm/km^2/yr.
Total deposition of sediment per year is 1.48 MCM/year considering sediment deposition upto 43 m. Sediment yield becomes 7.08 mm/km^2/yr.

3. Seriousness of Problem:-

According to IS 12182 – 1987 1987"Guidelines for Determination of Effects of Sedimentation in Planning and Performance of Reservoirs" 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 ran be neglected for studies of reservoir performance. For cases falling between these two limits, the sedimentation problem is considered significant and requires further studies.

For Salaulim Dam upto FRL capacity is 208.823 MCM

Sediment deposition per year = 0.69 MCM upto FRL

Average annual volume of sediment deposition with the gross capacity of the reservoir = 0.69/208.823 = 0.33% which is between 0.1% and 0.5%. **The sediment problem is significant.**

For Salaulim Dam upto 43 m capacity is 253.469 MCM

Sediment deposition per year = 1.48 MCM upto FRL

Average annual volume of sediment deposition with the gross capacity of the reservoir = 1.48/253.469 = 0.58% which is greater than 0.5%. **The sediment problem is serious**.

4. Area-reduction method:-

The Elevation-Area-Capacity curve and is produced for another 100 years at 10 years interval using Area-reduction method. Year 2021 is considered as base year. Elevation-Area-Capacity surveyed in 2021 is used as a base data. Elevation-Area-Capacity for 2021 is shown in Table 0-3

Table 0-2   Elevation-Area-Capacity in 2021

Elevation m	Area ha	Capacity MCM	Elevation m	Area ha	Capacity MCM	Elevation m	Area ha	Capacity MCM
45.5	2918.1	321.64	30	801.1183	43.67	14.6	32.91868	0.911
45	2843.7	307.24	29.6	762.5418	40.54	14	27.86024	0.729
44.6	2783.5	295.98	29	705.8325	36.14	13.4	23.30998	0.575
44	2688.9	279.57	28.4	651.3386	32.07	13	20.44833	0.488
43.4	2590.1	263.72	28	614.3347	29.54	12.5	17.26118	0.394
43	2536.7	253.47	27.5	568.7174	26.58	12	14.51147	0.314
42.5	2466.9	240.96	27	520.5716	23.85	11.6	12.64436	0.260004

Elevation m	Area ha	Capacity MCM	Elevation m	Area ha	Capacity MCM	Elevation m	Area ha	Capacity MCM
42	2403.7	228.78	26.6	481.603	21.85	11	10.06979	0.192
41.6	2353.1	219.27	26	414.5378	19.16	10.4	7.795105	0.139
41.15	**2285.6**	**208.82**	25.4	368.895	16.81	10	6.605692	0.110
40.4	2192.5	192.03	25	345.0154	15.38	9.5	5.19429	0.080
40	2126.7	183.37	24.5	316.643	13.73	9	3.89079	0.058
39.5	2048.2	172.94	24	285.4105	12.23	8.6	2.971563	0.044
39	1966.6	162.90	23.6	261.9817	11.13	8	1.899422	0.029
38.6	1899.8	155.16	23	228.6409	9.66	7.4	1.176786	0.020
38	1792.2	144.08	22.4	201.915	8.37	7	0.930193	0.016
37.4	1688.1	133.65	22	186.1824	7.60	6.5	0.706429	0.012
37	1629.7	127.01	21.5	166.7428	6.71	6	0.557075	0.009001
36.5	1562.6	119.03	21	148.3224	5.93	5.6	0.454115	0.0070
36	1499.1	111.38	20.6	134.2512	5.36	5	0.3341	0.0046
35.6	1447.7	105.49	20	116.987	4.61	4.4	0.243101	0.0029
35	1369	97.04	19.4	102.9365	3.95	4	0.183071	0.002054
34.4	1293.6	89.05	19	94.85307	3.55	3.5	0.127153	0.001282
34	1241.7	83.98	18.5	85.46016	3.10	3	0.087731	0.000751
33.5	1176.1	77.93	18	76.70506	2.70	2.6	0.06631	0.000444
33	1113.9	72.21	17.6	70.00204	2.40	2	0.036819	0.000135
32.6	1067.4	67.85	17	60.94188	2.01	1.4	0.007135	0.000040
32	1001.1	61.65	16.4	52.67133	1.67	1	0.004086	0.000017
31.4	938.1	55.83	16	47.70141	1.47	0.5	0.001463	0.000004
31	897.15	52.16	15.5	42.02029	1.25	0	0	0.000000
30.5	848.63	47.80	15	36.82968	1.05			

The steps and results are described in this section.

Determine sediment inflow: Volume of sediment deposition is determined from 1984 and 2021survey. Deposition of sediment volume is25.537 mcm upto FRL. Deposition of sediment volume per year is 0.69 MCM upto FRL.

Selection of design curve: Strand and Pemberton state that the reservoir does not change type

with continued sediment deposition unless reservoir operation changes. Thus, the stage-capacity plot should be based on the original reservoir bathymetry, not the bathymetry following sediment accumulation. The original depth-capacity (1984) relationship on log-log paper is plotted and the slope m of the fitted line, which is the reciprocal of the slope of the depth versus capacity plot (Figure 0-5) is calculated. When the slope m does not plot as a straight line, shape type corresponding to the predominate overall slope, or the slope in the area of the reservoir where most of the sediment will deposit, are used. It is noticed that slope m is following straight line above depth 0.2 m i.e., between 17 m and 43 m and it is predominant. Therefore, slope in this area is used.

Figure 0-2   Reservoir depth-capacity relationship forsalaulim Reservoir

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

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

The type curves in Figure 0-5 reflect the tendency for sediment is Floodplain-foothill reservoir i.e., type II.

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

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

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

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

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

Figure 0-6 shows the plotting off f (p) against relative reservoir depth, p, for the four types of reservoirs and value is given in Table 0-4.

Figure 0-3   Type curves for determining the new zero depth at the dam.

Table 0-3   Values of the Functionf(p) for the Four Types of Reservoirs

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

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

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

Where S = total sediment deposition, V_h = reservoir capacity (m³) at a given elevation h, H = original depth of reservoir below normal pool, A_h= reservoir area (m²) at a given elevation h.

The relative depth p is computed as

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

Where h_{min} = original bottom elevation

The resulting F and p values on the type curves are presented in Figure 0-7. The intersection of the plotted F values with the type of curve selected for the reservoir defines the p_0 value for the new zero-capacity elevation at the dam. Intersection occurs at p_0 = 0.283, 0.46, 0.558 for 10 yr, 50 yr and 100 yr respectively.

Figure 0-4   Type curves for determining the new zero depth at the dam based on thedimensionless Ffunction.

The new zero-capacity elevation is given by $h_0 = (p_0H + h_{min}) = 0.283 (45.5-0) + 45.5 = 12.876$ m for 10 yr. Area corresponding to zero-capacity elevation is computed from original elevation area-capacity curve.

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

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

The relative sediment area 'a' at the new zero elevation is computed for 10 yr, a = 1.0567 and the area correction factor is A0/a = 18.519.

Figure 0-5   Sediment distribution – Area design curves (Based on reservoir storage curve)

Using aforesaid methodology Elevation-Area-Capacity curve is estimated for every 10-year upto 100 year considering 2021 as base year. Figure 0-9and Table 0-5 shows Elevation-capacity for 10, 30, 50, 70 and 100 year. A sample calculation is given in Appendix A for 30 year.
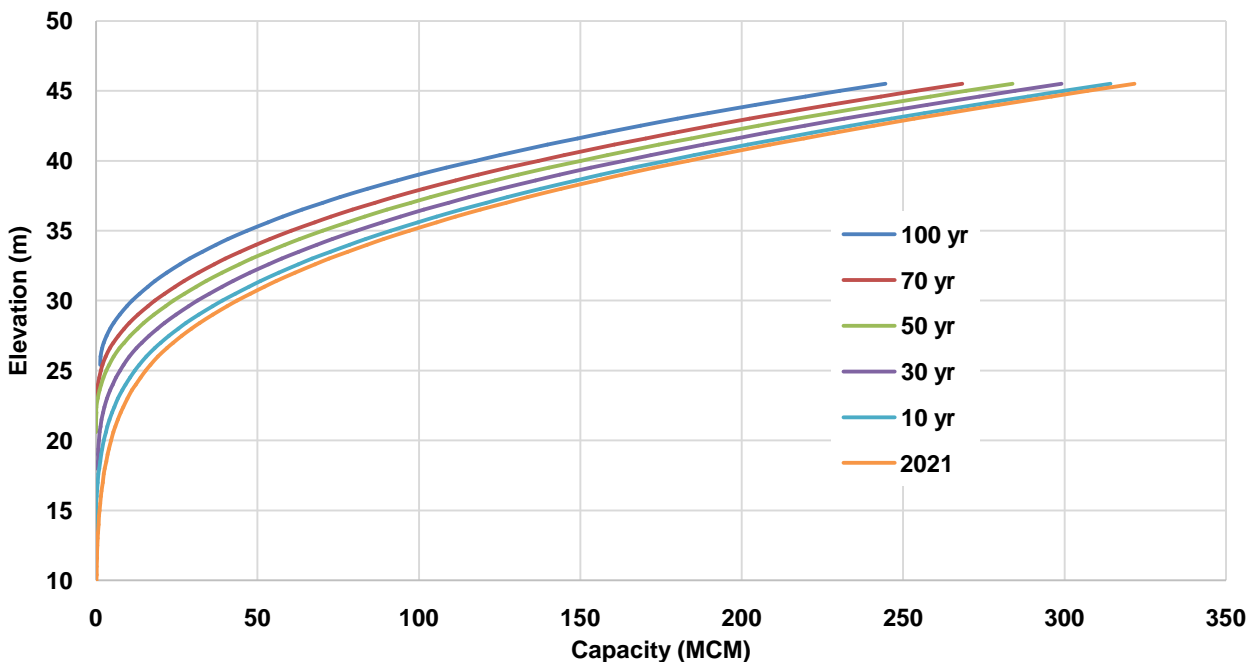
Figure 0-6   Elevation-capacity curve for different year for Salaulim Reservoir

Table 0-4   Elevation-capacity for different year for Salaulim Reservoir

Elevation (m)	Capacity (MCM)					
	2021	10yr	30yr	50yr	70yr	100yr
45.50	321.641	314.222	299.067	283.854	268.277	244.557
45.00	307.237	299.836	284.728	269.564	254.049	230.434
44.60	295.982	288.615	273.591	258.516	243.113	219.689
44.00	279.574	272.267	257.403	242.494	227.299	204.230
43.40	263.722	256.487	241.810	227.096	212.147	189.495
43.00	253.469	246.286	231.746	217.176	202.408	180.062
42.50	240.956	233.843	219.487	205.109	190.581	168.646
42.00	228.780	221.742	207.582	193.407	179.136	157.637
41.60	219.266	212.291	198.295	184.291	170.236	149.102
41.15	208.823	201.921	188.117	174.314	160.510	139.804
40.40	192.033	185.260	171.791	158.337	144.973	125.014
40.00	183.374	176.672	163.389	150.128	137.008	117.465
39.50	172.939	166.327	153.283	140.272	127.465	108.454
39.00	162.896	156.379	143.581	130.825	118.340	99.876
38.60	155.164	148.723	136.125	123.579	111.357	93.340
38.00	144.078	137.755	125.465	113.239	101.421	84.090
37.40	133.648	127.446	115.471	103.574	92.169	75.541
37.00	127.014	120.893	109.132	97.458	86.334	70.182
36.50	119.034	113.017	101.527	90.136	79.368	63.821
36.00	111.381	105.469	94.255	83.151	72.743	57.811
35.60	105.487	99.660	88.669	77.798	67.683	53.248
35.00	97.037	91.340	80.688	70.169	60.499	46.820
34.40	89.051	83.485	73.177	63.016	53.797	40.883
34.00	83.980	78.503	68.426	58.507	49.591	37.193
33.50	77.935	72.569	62.784	53.169	44.635	32.888

Elevation (m)	Capacity (MCM)					
	2021	10yr	30yr	50yr	70yr	100yr
33.00	72.211	66.958	57.467	48.159	40.011	28.919
32.60	67.849	62.686	53.432	44.371	36.534	25.971
32.00	61.646	56.619	47.724	39.036	31.669	21.904
31.40	55.829	50.941	42.406	34.094	27.201	18.240
31.00	52.159	47.363	39.070	31.011	24.434	16.013
30.50	47.795	43.115	35.126	27.383	21.205	13.460
30.00	43.671	39.108	31.424	23.998	18.220	11.156
29.60	40.544	36.074	28.635	21.465	16.008	9.489
29.00	36.138	31.809	24.738	17.952	12.978	7.281
28.40	32.066	27.879	21.177	14.776	10.287	5.414
28.00	29.535	25.442	18.987	12.844	8.679	4.356
27.50	26.577	22.602	16.457	10.635	6.875	3.241
27.00	23.852	19.995	14.158	8.660	5.305	2.361
26.60	21.847	18.085	12.496	7.256	4.226	1.834
26.00	19.157	15.536	10.319	5.466	2.923	1.358
25.40	16.812	13.333	8.487	4.021	1.965	0
25.00	15.385	12.001	7.402	3.193	1.462	
24.50	13.730	10.464	6.174	2.287	0.960	
24.00	12.225	9.077	5.095	1.529	0.606	
23.60	11.131	8.076	4.340	1.031	0.431	
23.00	9.661	6.747	3.379	0.453	0.335	
22.40	8.371	5.597	2.596	0.052	0	
22.00	7.595	4.914	2.156	0.039		
21.50	6.713	4.148	1.693	0.026		
21.00	5.925	3.476	1.322	0.013		
20.60	5.360	3.002	1.089	0		
20.00	4.608	2.387	0.832			

Elevation (m)	Capacity (MCM)					
	2021	10yr	30yr	50yr	70yr	100yr
19.40	3.950	1.864	0.665			
19.00	3.554	1.559	0.595			
18.50	3.103	1.220	0.548			
18.00	2.698	0.925	0			
17.60	2.405	0.720				
17.00	2.012	0.458				
16.40	1.672	0.247				
16.00	1.471	0.132				
15.50	1.247	0.014				
15.00	1.050	0.011				
14.60	0.911	0.009				
14.00	0.729	0.007				
13.40	0.575	0.005				
13.00	0.488	0.002				
12.50	0.394	0				
12.00	0.314					
11.60	0.260					
11.00	0.192					
10.40	0.139					
10.00	0.110					
9.50	0.080					
9.00	0.058					
8.60	0.044					
8.00	0.029					
7.40	0.020					
7.00	0.016					
6.50	0.012					

Elevation (m)	Capacity (MCM)					
	2021	**10yr**	**30yr**	**50yr**	**70yr**	**100yr**
6.00	0.009					
5.60	0.007					
5.00	0.005					
4.40	0.003					
4.00	0.0021					
3.50	0.0013					
3.00	0.0008					
2.60	0.0004					
2.00	0.00014					
1.40	0.000040					
1.00	0.000017					
0.50	0.000004					
0.00	0.000000					

New zero elevation at every 10 year is given in Table 0-6.

Table 0-5   New zero elevation at every 10 years

Year	New Zero Elevation (m)	Year	New Zero Elevation (m)
10 yr	12.5	60 yr	22
20 yr	16	70 yr	22.4
30 yr	18	80 yr	23.6
40 yr	19.4	90 yr	24.5
50 yr	20.6	100 yr	25.4

It is observed from the study that capacity of reservoir at FRL is reduced from 208.49 MCM to 139.80 139.80 MCM in 100 years. Total reservoir capacity at every 10 year is depicted in Figure 0-10.

Figure 0-7   Comparison of reduced reservoir capacity at FRL (10-year interval)

Limitation on sediment study:-

Sediments are deposited in reservoirs at all elevations, causing the stage-capacity curve to shift. Empirical methods have been developed to distribute sediment deposits within a reservoir as a function of depth, thereby projecting the shift in the stage-storage curve. These methods are much quicker and easier to use than mathematical modeling and also require less data. When sediment survey data are available for an existing reservoir, the observed deposition pattern can be used to select the proper empirical relationship to compute the future shift in the stage-area and stage-capacity relationships. As a limitation, empirical methods do not identify the specific locations in a reservoir which will be affected by sediment; they predict only the change in the stage-area and stage-capacity curves. A significant shift in the operating regime, such as implementation of sediment management, will affect the deposition pattern. Empirical methods cannot be user to simulate these effects, and the evaluation of management alternatives requires numerical modeling

Table-III

CAPACITY OF SALAULIM DAM FOR DIFFERENT YEAR:-

Capacity of Salaulim Dam (Acre ft, MCM) was computed up to E.l. 141.08 ft. (43.00 m). The Below table shows Dam capacity at 3 feet (1m) depth interval in different year as here under:-

YEAR		1984		2021	
Elevation ft above M.S.L	Elevation mtr above M.S.L	Capacity in Acre Ft	Capacity in MCM	Capacity in Acre Ft	Capacity in MCM
32.81	10.00	0.000	0.000	89.178	0.110
36.09	11.00	121.607	0.150	155.657	0.192
39.37	12.00	243.214	0.300	254.564	0.314
42.65	13.00	364.821	0.450	395.628	0.488
45.93	14.00	486.428	0.600	591.010	0.729
49.21	15.00	1248.498	1.540	851.249	1.050
52.49	16.00	1337.677	1.650	1192.559	1.471
55.77	17.00	1459.284	1.800	1631.155	2.012
59.06	18.00	2432.140	3.000	2187.304	2.698
62.34	19.00	3404.995	4.200	2881.275	3.554
65.62	20.00	5253.421	6.480	3735.766	4.608
66.99	**20.42**	5702.557	**7.034**	4154.094	**5.124**
68.90	21.00	6323.563	7.800	4803.476	5.925
72.18	22.00	8755.702	10.800	6157.367	7.595
73.82	22.50	9971.772	12.300	6994.833	8.628
75.46	23.00	11187.842	13.800	7832.300	9.661
78.74	24.00	14106.409	17.400	9910.969	12.225
82.02	25.00	17746.512	21.890	12472.822	15.385
85.30	26.00	21402.828	26.400	15530.832	19.157
88.58	27.00	26267.107	32.400	19337.131	23.852
91.86	28.00	31131.386	38.400	23944.414	29.535
95.14	29.00	37941.377	46.800	29297.553	36.138
98.43	30.00	44500.047	54.890	35404.655	43.671
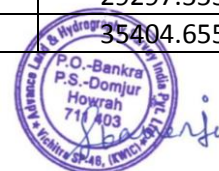
YEAR		1984		2021	
Elevation ft above M.S.L	Elevation mtr above M.S.L	Capacity in Acre Ft	Capacity in MCM	Capacity in Acre Ft	Capacity in MCM
101.71	31.00	53020.642	65.400	42285.989	52.159
104.99	32.00	63235.628	78.000	49977.225	61.646
108.27	33.00	74423.470	91.800	58542.410	72.211
111.55	34.00	86584.168	106.800	68083.693	83.980
114.83	35.00	94504.836	116.570	78669.175	97.037
118.11	36.00	111878.419	138.000	90298.045	111.381
121.39	37.00	126471.256	156.000	102971.924	127.014
123.03	37.50	133999.539	165.286	109888.929	135.546
124.67	38.00	141550.522	174.600	116805.934	144.078
127.95	39.00	156629.787	193.200	132061.935	162.896
131.23	40.00	171992.802	212.150	148663.719	183.374
134.51	41.00	187761.173	231.600	166527.784	205.409
135.01	**41.15**	189706.885	**234.000**	169295.559	**208.823**
137.80	42.00	200862.298	247.760	185474.962	228.780
139.44	42.50	219999.183	271.365	195482.405	241.124
141.08	43.00	249983.410	308.350	205490.660	253.469

Table 6-Elevation wise Capacity in the year between 1984 & 2021

Table-IIIA

- **Elevation wise Capacity (0.3m interval) of Salaulim Dam in the Year 2021:-**

Elevation in ft.	Elevation in m.	Capacity in Acre ft.	Capacity in MCM	Elevation in ft.	Elevation in m.	Capacity in Acre ft.	Capacity in MCM	Elevation in ft.	Elevation in m.	Capacity in Acre ft.	Capacity in MCM	Elevation in ft.	Elevation in m.	Capacity in Acre ft.	Capacity in MCM
-0.3	-0.1	0.000	0.000	40.0	12.2	278.885	0.344	80.4	24.5	11131.092	13.730	121.4	37.0	102971.924	127.014
0.0	0.0	0.000	0.000	41.0	12.5	319.421	0.394	81.4	24.8	11922.348	14.706	121.7	37.1	104299.062	128.651
0.7	0.2	0.000	0.000	42.0	12.8	363.200	0.448	82.0	25.0	12472.822	15.385	122.7	37.4	108350.195	133.648
1.6	0.5	0.000	0.000	42.7	13.0	395.628	0.488	82.3	25.1	12754.950	15.733	123.7	37.7	112514.829	138.785
2.6	0.8	0.000	0.000	43.0	13.1	411.842	0.508	83.3	25.4	13629.710	16.812	124.7	38.0	116805.934	144.078
3.3	1.0	0.000	0.000	44.0	13.4	466.16	0.575	84.3	25.7	14552.302	17.950	125.7	38.3	121234.049	149.540
3.6	1.1	0.000	0.000	44.9	13.7	525.342	0.648	85.3	26.0	15530.832	19.157	126.6	38.6	125793.500	155.164
4.6	1.4	0.000	0.000	45.9	14.0	591.010	0.729	86.3	26.3	16580.706	20.452	127.6	38.9	130474.558	160.938
5.6	1.7	0.000	0.000	46.9	14.3	661.542	0.816	87.3	26.6	17711.651	21.847	128.0	39.0	132061.935	162.896
6.6	2.0	0.000	0.000	47.9	14.6	738.560	0.911	88.3	26.9	18918.803	23.336	128.6	39.2	135278.844	166.864
7.5	2.3	0.000	0.000	48.9	14.9	822.063	1.014	88.6	27.0	19337.131	23.852	129.6	39.5	140203.927	172.939
8.5	2.6	0.000	0.000	49.2	15.0	851.249	1.050	89.2	27.2	20197.298	24.913	130.6	39.8	145241.699	179.153
9.5	2.9	0.811	0.001	49.9	15.2	912.863	1.126	90.2	27.5	21546.324	26.577	131.2	40.0	148663.719	183.374
9.8	3.0	0.811	0.001	50.9	15.5	1010.959	1.247	91.2	27.8	22963.451	28.325	131.6	40.1	150398.645	185.514
10.5	3.2	0.811	0.001	51.8	15.8	1117.163	1.378	91.9	28.0	23944.414	29.535	132.5	40.4	155683.684	192.033
11.5	3.5	0.811	0.001	52.5	16.0	1192.559	1.471	92.2	28.1	24446.245	30.154	133.5	40.7	161061.145	198.666
12.5	3.8	1.621	0.002	52.8	16.1	1231.473	1.519	93.2	28.4	25996.329	32.066	134.5	41.0	166527.784	205.409
13.1	4.0	1.621	0.002	53.8	16.4	1355.510	1.672	94.2	28.7	27613.702	34.061	135.0	41.2	169295.559	208.823
13.5	4.1	1.621	0.002	54.8	16.7	1488.469	1.836	95.1	29.0	29297.553	36.138	135.5	41.3	172090.087	212.270
14.4	4.4	2.432	0.003	55.8	17.0	1631.155	2.012	96.1	29.3	31048.693	38.298	136.5	41.6	177761.837	219.266
15.4	4.7	3.243	0.004	56.8	17.3	1785.190	2.202	97.1	29.6	32869.555	40.544	137.5	41.9	183530.872	226.382
16.4	5.0	0.015	0.005	57.7	17.6	1949.765	2.405	98.1	29.9	34759.328	42.875	137.8	42.0	185474.962	228.780
17.4	5.3	4.054	0.006	58.7	17.9	2125.690	2.622	98.4	30.0	34759.328	43.671	138.5	42.2	189392.328	233.612
18.4	5.6	5.675	0.007	59.1	18.0	2187.304	2.698	99.1	30.2	36718.821	45.292	139.4	42.5	195346.206	240.956
19.4	5.9	6.486	0.008	59.7	18.2	2314.586	2.855	100.1	30.5	38748.037	47.795	140.4	42.8	201398.990	248.422
19.7	6.0	7.296	0.009	60.7	18.5	2515.643	3.103	101.0	30.8	40847.784	50.385	141.1	43.0	205490.660	253.469
20.3	6.2	8.107	0.010	61.7	18.8	2730.482	3.368	101.7	31.0	42285.989	52.159	141.4	43.1	207552.303	256.012
21.3	6.5	9.729	0.012	62.3	19.0	2881.275	3.554	102.0	31.1	43018.063	53.062	142.4	43.4	213802.902	263.722
22.3	6.8	11.351	0.014	62.7	19.1	2959.103	3.650	103.0	31.4	45261.306	55.829	143.4	43.7	220168.622	271.574
23.0	7.0	12.971	0.016	63.6	19.4	3202.317	3.950	104.0	31.7	47580.757	58.690	144.4	44.0	226654.327	279.574
23.3	7.1	13.782	0.017	64.6	19.7	3460.124	4.268	105.0	32.0	49977.225	61.646	145.3	44.3	233247.857	287.707
24.3	7.4	16.214	0.020	65.6	20.0	3735.766	4.608	106.0	32.3	52451.521	64.698	146.3	44.6	239956.509	295.982
25.3	7.7	19.457	0.024	66.6	20.3	4030.866	4.972	107.0	32.6	55006.079	67.849	147.3	44.9	246781.903	304.401
26.2	8.0	23.511	0.029	67.0	20.4	4154.094	5.124	107.9	32.9	57644.139	71.103	147.6	45.0	249081.086	307.237
27.2	8.3	29.054	0.036	67.6	20.6	4345.423	5.360	108.3	33.0	58542.410	72.211	148.3	45.2	253715.933	312.954
28.2	8.6	35.671	0.044	68.6	20.9	4685.111	5.779	108.9	33.2	60368.136	74.463	149.3	45.5	260758.599	321.641
29.2	8.9	43.779	0.054	68.9	21.0	4803.476	5.925	109.9	33.5	63182.932	77.935				
29.5	9.0	47.021	0.058	69.6	21.2	5049.932	6.229	110.9	33.8	66091.771	81.523				
30.2	9.2	53.507	0.066	70.5	21.5	5442.318	6.713	111.5	34.0	68083.693	83.980				
31.2	9.5	64.857	0.080	71.5	21.8	5862.267	7.231	111.9	34.1	69096.274	85.229				

Elevation in ft.	Elevation in m.	Capacity in Acre ft.	Capacity in MCM	Elevation in ft.	Elevation in m.	Capacity in Acre ft.	Capacity in MCM	Elevation in ft.	Elevation in m.	Capacity in Acre ft.	Capacity in MCM	Elevation in ft.	Elevation in m.	Capacity in Acre ft.	Capacity in MCM
32.2	9.8	78.639	0.097	72.2	22.0	6157.367	7.595	112.9	34.4	72194.820	89.051				
32.8	10.0	89.178	0.110	72.5	22.1	6309.781	7.783	113.8	34.7	75386.597	92.988				
33.1	10.1	94.043	0.116	73.5	22.4	6786.480	8.371	114.8	35.0	78669.175	97.037				
34.1	10.4	112.690	0.139	74.5	22.7	7293.176	8.996	115.8	35.3	82046.606	101.203				
35.1	10.7	132.146	0.163	75.5	23.0	7832.300	9.661	116.8	35.6	85519.701	105.487				
36.1	11.0	155.657	0.192	76.4	23.3	8407.906	10.371	117.8	35.9	89087.650	109.888				
37.1	11.3	181.600	0.224	77.4	23.6	9024.048	11.131	118.1	36.0	90298.044	111.381				
38.1	11.6	210.785	0.260	78.4	23.9	9682.348	11.943	118.8	36.2	92748.831	114.404				
39.0	11.9	243.214	0.300	78.7	24.0	9910.969	12.225	119.8	36.5	96502.432	119.034				
39.4	12.0	254.564	0.314	79.4	24.2	10383.614	12.808	120.7	36.8	100351.699	123.782				

Table 7- Elevation wise Capacity (0.3m interval) of Salaulim Dam in the Year 2021

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.

Table-IV

Loss of Storage Capacity in Salaulim Dam

Period	No. of years	Total volume of Loss of Capacity		Average Annual loss of Capacity	
		Acre Feet	10^6 m^3	Acre Feet	10^6 m^3
1984-2021	37	20703.19	26	560	0.7

Table-V

Having taken the Drainage area of Salaulim Dam = 80.70 Sq, Miles (209 Sq. Km) upto the dam area.

Sediment Deposition Rate in Salaulim Dam

Between Years	No. of years	Volume of Deposit		Sediment Deposition Rate	
		Acre feet	MM^3	Aft./Sq. mile/year	M3/Sq km/year
1984-2021	37	20703.19	25.53	6.93	3302

Table-VI

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

EL IN M.	CAP IN MCM		CAP-LOSS 1997-2020	LOSS OF CAP IN DEAD ZONE			
	1984	2021		EL	20.42	-0.10	CAPACITY
42.50	271.365	241.124	30.24	**YEAR**	**CAP IN MCM**		
42.00	247.760	228.780	18.98	1984	7.034	0.000	7.03
41.15	**234.000**	**208.823**	**25.18**	2021	5.124	0.000	5.12
41.00	231.600	205.409	26.19	**LOSS OF CAP IN DEAD ZONE**			**1.91**
40.00	212.150	183.374	28.78				
39.00	193.200	162.896	30.30	**LOSS OF CAP IN LIVE ZONE**			
38.00	174.600	144.078	30.52	**EL**	41.15	20.42	**LIVE CAP**
37.50	165.286	135.546	29.740	**YEAR**	**CAP IN MCM**		
37.00	156.000	127.014	28.99	1984	234.000	7.034	226.97
36.00	138.000	111.381	26.62	2021	208.823	5.124	203.70
35.00	116.570	97.037	19.53	**LOSS OF CAP IN LIVE ZONE**			**23.27**
34.00	106.800	83.980	22.82				
33.00	91.800	72.211	19.59				
32.00	78.000	61.646	16.35	**Total loss of Capacity- 25.18 MCM**			
31.00	65.400	52.159	13.24				
30.00	54.890	43.671	11.22				
29.00	46.800	36.138	10.66				
28.00	38.400	29.535	8.86				
27.00	32.400	23.852	8.55				
26.00	26.400	19.157	7.24				
25.00	21.890	15.385	6.51				
24.00	17.400	12.225	5.17				
23.00	13.800	9.661	4.14				
22.50	12.300	8.628	3.67				
22.00	10.800	7.595	3.20				
21.00	7.800	5.925	1.87				
20.42	**7.034**	**5.124**	**1.91**				
20.00	6.480	4.608	1.87				
19.00	4.200	3.554	0.65				
18.00	3.000	2.698	0.30				
17.00	1.800	2.012	-0.21				
16.00	1.650	1.471	0.18				
15.00	1.540	1.050	0.49				
14.00	0.600	0.729	-0.13				
13.00	0.450	0.488	-0.04				
12.00	0.300	0.314	-0.01				
11.00	0.15	0.192	-0.04				
10.00	0.00	0.110	-0.11				
-0.10	**0.000**	**0.000**	0.00				
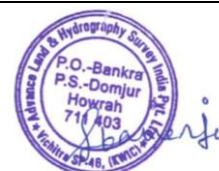
- **Graph of Loss of Capacity in the Year between 1984 and 2021:-**
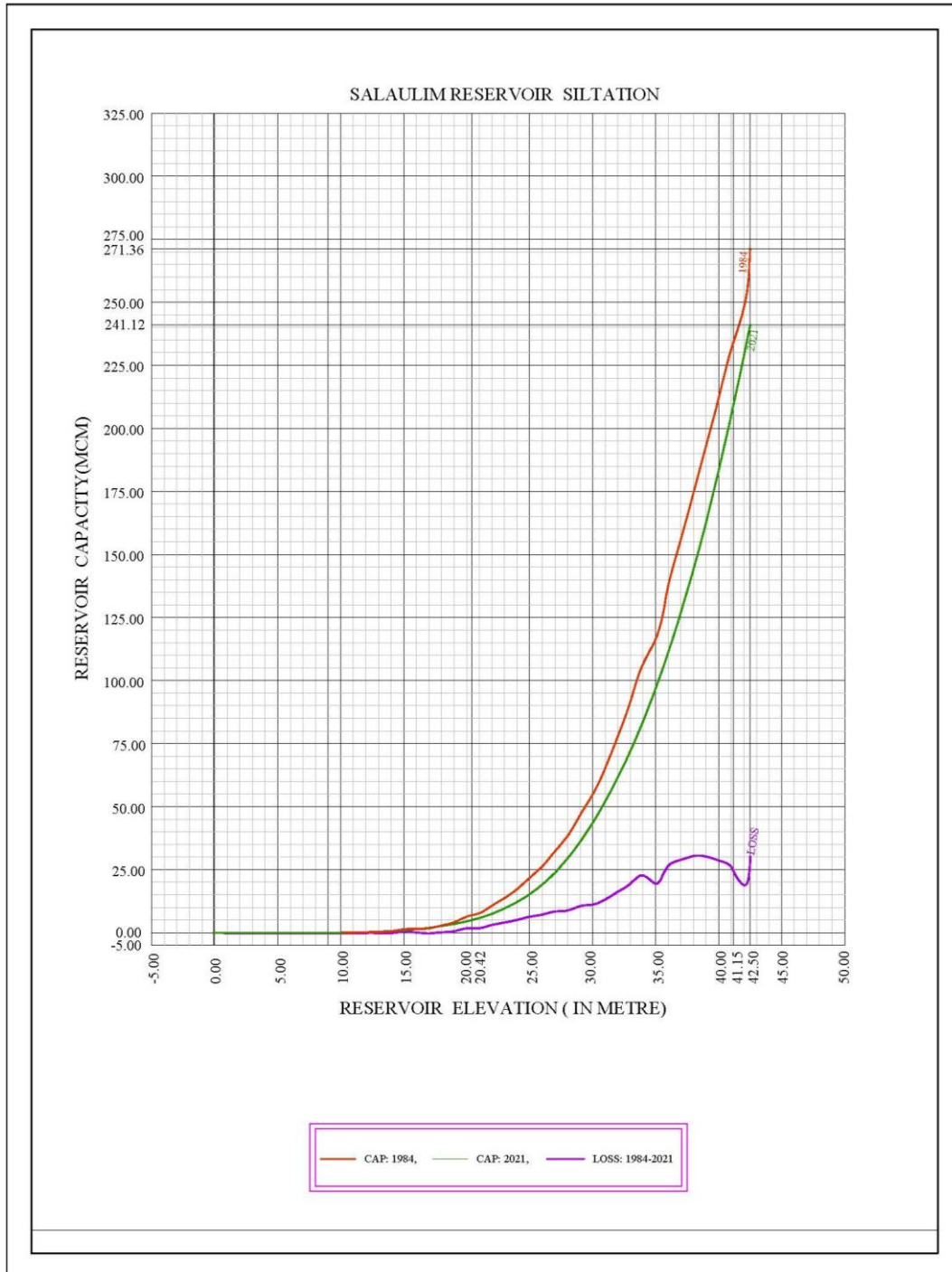
Figure 8 - Graph of Loss of Capacity in the Year between 1984 and 2021

Table-VII

Depth Wise location of Deposit in Percentage of Salaulim Dam

DEPTH WISE LOCATION OF DEPOSIT IN SALAULIM DAM (PERCENTAGE OF TOTAL DEPOSIT)										
BETWEEN EL.(FT/M)	33-43 (10-13)	43-53 (13-16)	53-63 (16-19)	63-73 (19-22)	73-83 (22-25)	83-93 (25-28)	93-103 (28-31)	103-113 (31-34)	113-123 (34-37)	123-135 (37-41.15)
DEPTH (FT/M)	0-10 (0-3.0)	10-20 (3.0-6.1)	20-30 (6.1-9.1)	30-40 (9.1-12.2)	40-50 (12.2-15.2)	50-60 (15.2-18.3)	60-70 (18.3-21.3)	70-80 (21.3-24.4)	80-90 (24.4-27.4)	90-102 (27.4-31.1)
2021	0.3	0.6	1.0	2.0	3.8	6.9	11.0	15.3	20.5	38.6
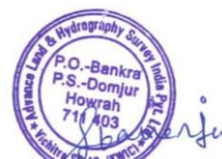
- **Depth wise Sedimentation graph of Salaulim Dam:-**
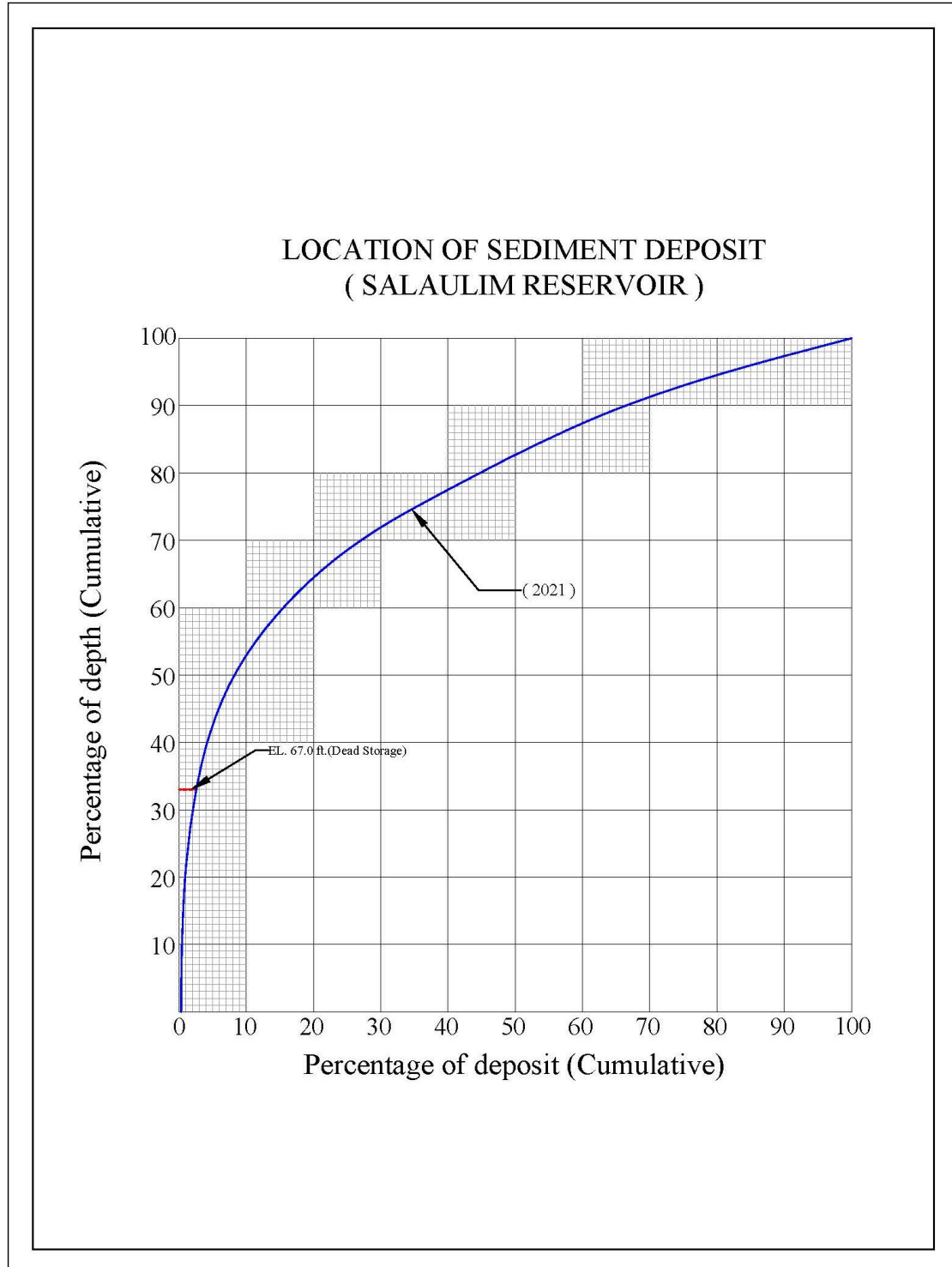
Figure 9- Graph of Depth wise sedimentation deposit of Salaulim Dam

- **Horizontal deposition plan of Salaulim Reservoir:-**
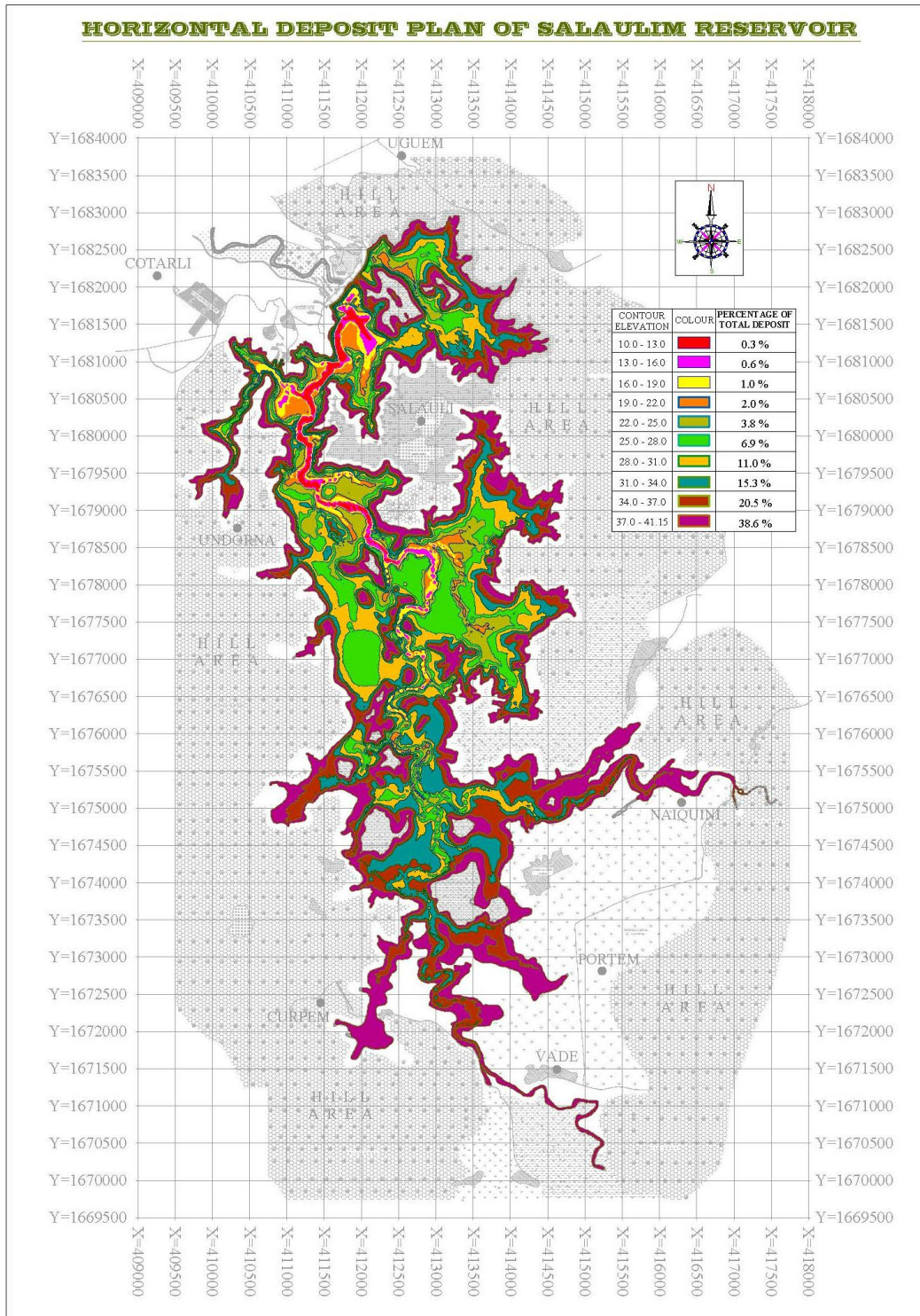
Figure 10-Horizontal Sediment Deposition Plan of Salaulim Reservoir

ANALYSIS OF BED MATERIAL SAMPLES (iv)

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

13.2 Analysis of bed Material Samples:-

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

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

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

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

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

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

13.2.1 Soil Sample Positions:-
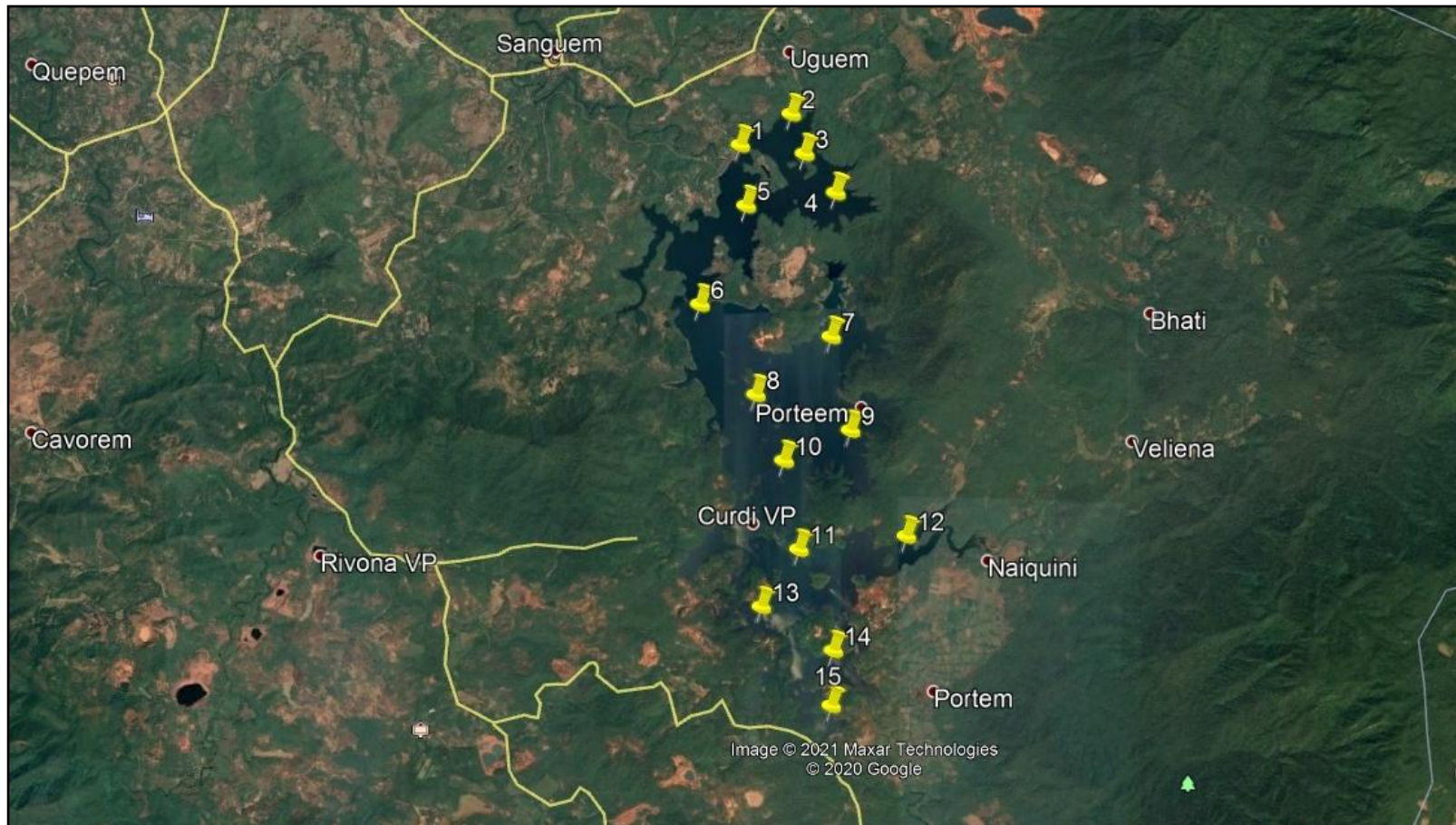
Figure 11-Locations of Soil Samples

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

				SITE: SALAULIM DAM							
				TEST RESULTS							
Sl. No.	Sample No.	Latitude (N)	Longitude (E)	Description	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Moisture Content (%)	Specific Gravity	Uniformity of soil
1	1	15°12'46.13"	74°10'47.21"	Reddish brownish, clayey silty sand mixed with gravels	14.54	35.76	25.70	24.00	64.37	2.652	Non-uniform
2	2	15°13'3.74"	74°11'17.17"	Deep brownish, clayey sand mixed with high percentage of gravels	43.10	16.56	19.54	20.80	55.51	2.660	Non-uniform
3	3	15°12'41.22"	74°11'24.99"	Deep grey, clayey silt mixed with sand and gravels	14.98	13.20	38.22	33.60	69.27	2.630	Non-uniform
4	4	15°12'19.10"	74°11'43.29"	Deep grey, clayey silt mixed with sand and gravels	11.00	15.00	37.20	36.80	65.00	2.625	Non-uniform
5	5	15°12'11.76"	74°10'50.70"	Deep brownish, clayey sand mixed with high percentage of gravels	39.00	21.00	17.60	22.40	52.00	2.657	Non-uniform
6	6	15°11'15.87"	74°10'23.60"	Deep grey, clayey silt mixed with sand and gravels	9.80	17.00	41.20	32.00	69.00	2.630	Non-uniform
7	7	15°10'57.62"	74°11'40.64"	Deep grey, clayey silt mixed with sand and gravels	14.00	12.00	40.40	33.60	62.70	2.635	Non-uniform
8	8	15°10'24.75"	74°10'56.44"	Deep grey, clayey silt mixed with sand and gravels	14.50	35.00	26.50	24.00	65.00	2.647	Non-uniform
9	9	15°10'4.59"	74°11'52.00"	Deep grey, clayey silt mixed with sand and gravels	11.00	17.00	40.00	32.00	71.00	2.639	Non-uniform
10	10	15°9'47.46"	74°11'12.98"	Deep grey, clayey silt mixed with sand and gravels	13.00	9.80	42.00	35.20	68.00	2.629	Non-uniform
11	11	15°8'57.27"	74°11'21.74"	Deep grey, clayey silt mixed with sand and gravels	15.00	13.70	34.50	36.80	65.90	2.635	Non-uniform
12	12	15°9'2.34"	74°12'24.36"	Deep grey, clayey silt mixed with sand and gravels	17.00	11.00	38.40	33.60	69.00	2.630	Non-uniform
13	13	15°8'24.88"	74°10'59.72"	Deep grey, clayey silt mixed with sand and gravels	14.00	13.00	37.80	35.20	64.50	2.634	Non-uniform
14	14	15°8'0.06"	74°11'41.92"	Reddish brownish, clayey silty sand mixed with gravels	11.00	31.00	30.80	27.20	66.10	2.649	Non-uniform
15	15	15°7'29.74"	74°11'42.35"	Deep grey, clayey silt mixed with sand and gravels	14.54	22.70	27.56	35.20	69.00	2.630	Non-uniform

13.2.4 Kramer's Coefficient:-

Kramer's coefficient

% Finer	Dia (mm)	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5	Sample-6	Sample-7	Sample-8	Sample-9	Sample-10	Sample-11	Sample-12	Sample-13	Sample-14	Sample-15
0	D0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	D10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	D20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	D30	0.0053	0.0085	-	-	0.0105	-	-	0.046	-	-	-	-	-	0.0037	-
40	D40	0.0147	0.0569	0.0043	0.0020	0.0750	0.0052	0.004	0.015	0.007	0.0030	0.0025	0.0052	0.0037	0.0090	0.0052
50	D50	0.0750	0.5000	0.0440	0.0144	0.4600	0.0600	0.050	0.075	0.047	0.0230	0.030	0.048	0.037	0.0230	0.0560
60	D60	0.3800	5.6000	5.6000	0.0680	4.0000	0.0680	0.068	0.130	0.068	0.0650	0.068	0.069	0.067	0.1000	0.072
70	D70	0.5600	6.3000	6.3000	0.0730	6.3000	0.0740	0.072	0.240	0.074	0.0700	0.074	0.074	0.072	0.2800	0.170
80	D80	1.4000	7.0000	7.0000	0.0540	8.1000	0.3200	0.500	0.052	1.500	0.0380	0.340	0.092	0.400	0.6000	0.500
90	D90	5.6000	8.5000	8.5000	5.3000	9.0000	4.0000	5.300	5.300	5.300	5.3000	5.300	5.300	5.300	5.6000	5.300
100	D100	6.3000	10.0000	10.0000	6.3000	10.0000	5.6000	6.300	6.300	6.300	6.3000	6.300	6.300	6.300	6.3000	6.300
84	D84	1.6000	7.4000	7.4000	0.7000	8.6000	0.5000	2.000	2.000	2.000	3.0000	2.000	3.000	1.200	0.7200	2.000
16	D16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
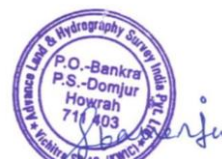
The grain sorting parameter (σ_g) indicates how well sorted sediment in riverbed; sorting parameter less than 1.6 represents well sorted sediment (Parker e book, ASCE, 2007). Sediment transport formulae applicable for uniform sediment (with median grain size, D50) can be applied in the sediment transport and morphological prediction. Sediment samples with values of σ_g in excess of 1.6 are said to be poorly sorted. The sorting parameter is nothing but geometric standard deviation estimated from grain size analysis. The corresponding geometric standard deviation σ_g are given as

$$\sigma_g = 2^{\sigma}$$

Where σ = standard deviation on psi scale

Table 1 shows geometric standard deviation and geometric mean for Salaulim Dam

Sample No	geometric mean size	geometric standard deviation	Remarks
Sample 1	0.0707	23.76	Non uniform and Poorly Sorted
Sample 2	0.0883	9.51	Non uniform and Poorly Sorted
Sample 3	0.0249	8.71	Non uniform and Poorly Sorted
Sample 4	0.0216	10.06	Non uniform and Poorly Sorted
Sample 5	0.0925	10.58	Non uniform and Poorly Sorted
Sample 6	0.0248	9.15	Non uniform and Poorly Sorted
Sample 7	0.0241	8.71	Non uniform and Poorly Sorted
Sample 8	0.0387	8.94	Non uniform and Poorly Sorted
Sample 9	0.0289	11.48	Non uniform and Poorly Sorted
Sample 10	0.0206	8.18	Non uniform and Poorly Sorted
Sample 11	0.0215	7.96	Non uniform and Poorly Sorted
Sample 12	0.0260	8.20	Non uniform and Poorly Sorted
Sample 13	0.0221	7.91	Non uniform and Poorly Sorted
Sample 14	0.0328	10.82	Non uniform and Poorly Sorted
Sample 15	0.0270	9.61	Non uniform and Poorly Sorted

13.2.5 Grain Size Distribution curves:-

Sample No - 1

Clay 24.00 %

Silt 25.70 %

Sand 35.76 %
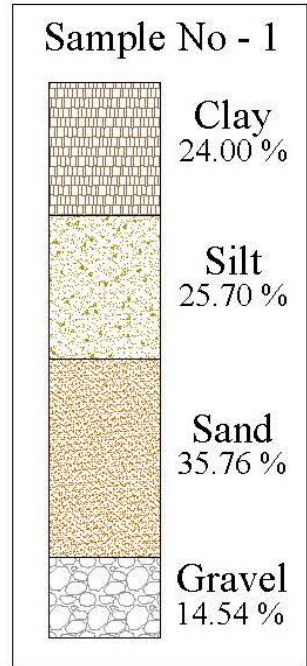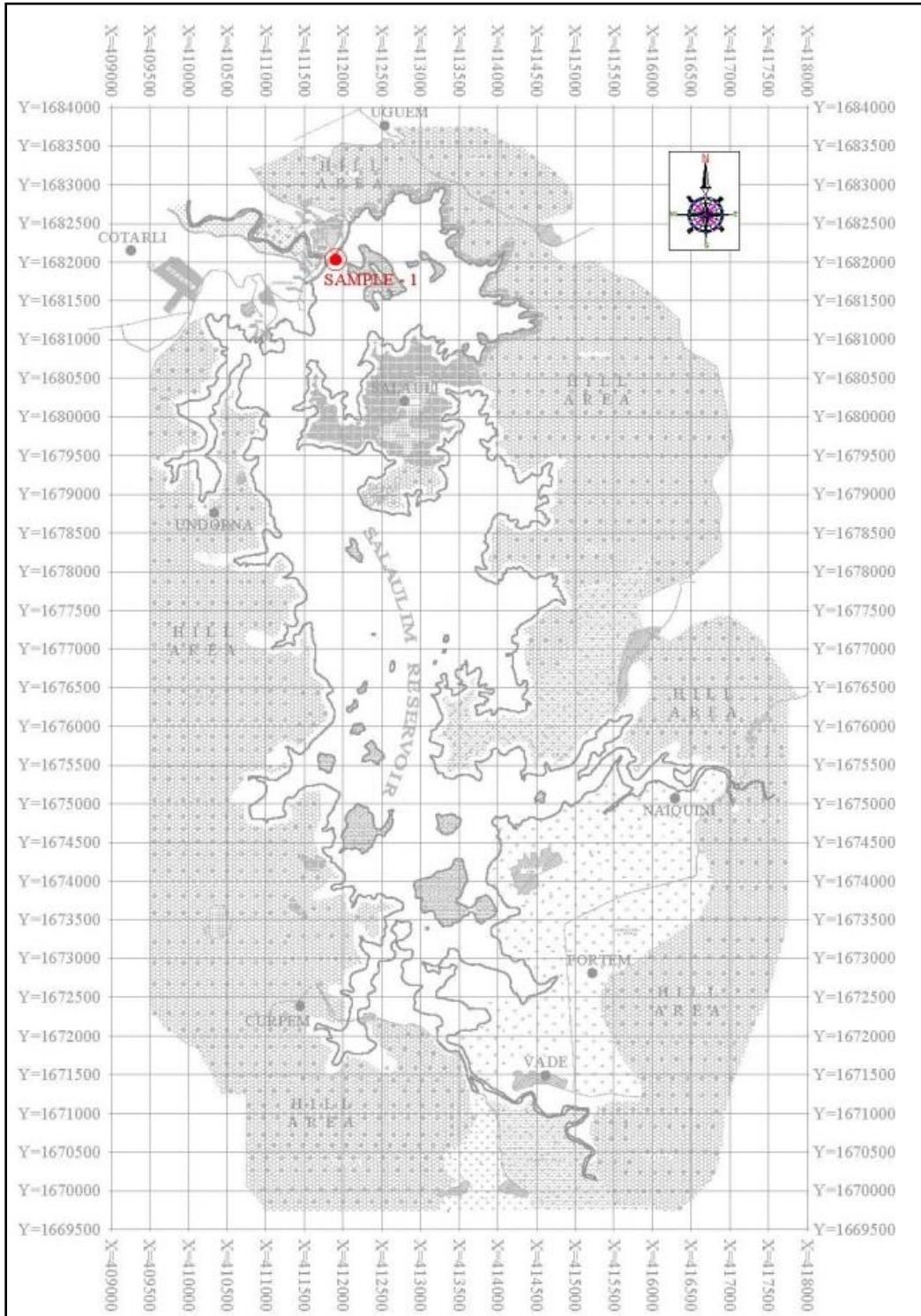
Gravel 14.54 %

GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	1
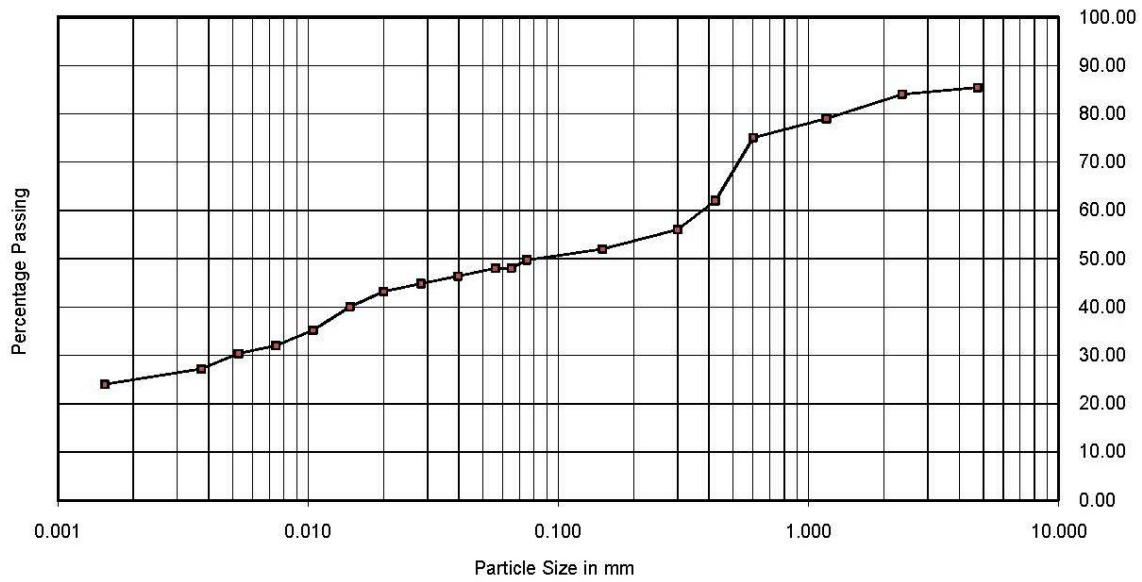
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
1	24.00	25.70	35.76	14.54

Sample No - 2
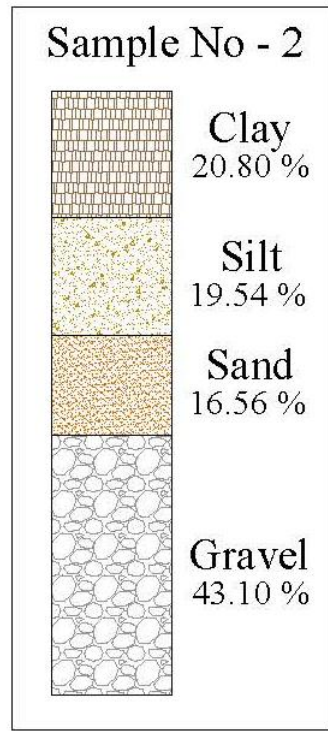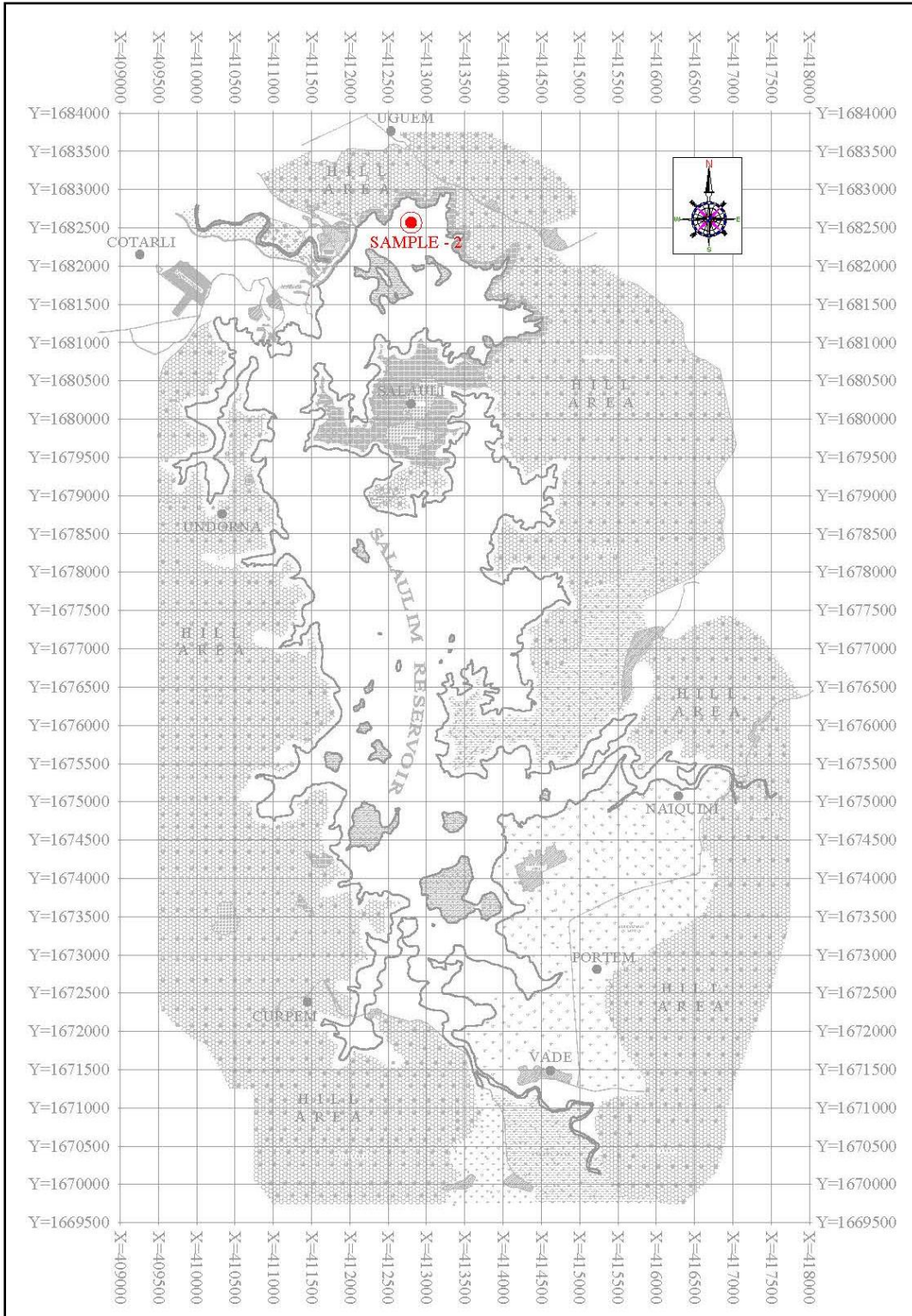
Clay
20.80 %

Silt
19.54 %

Sand
16.56 %

Gravel
43.10 %

GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	2
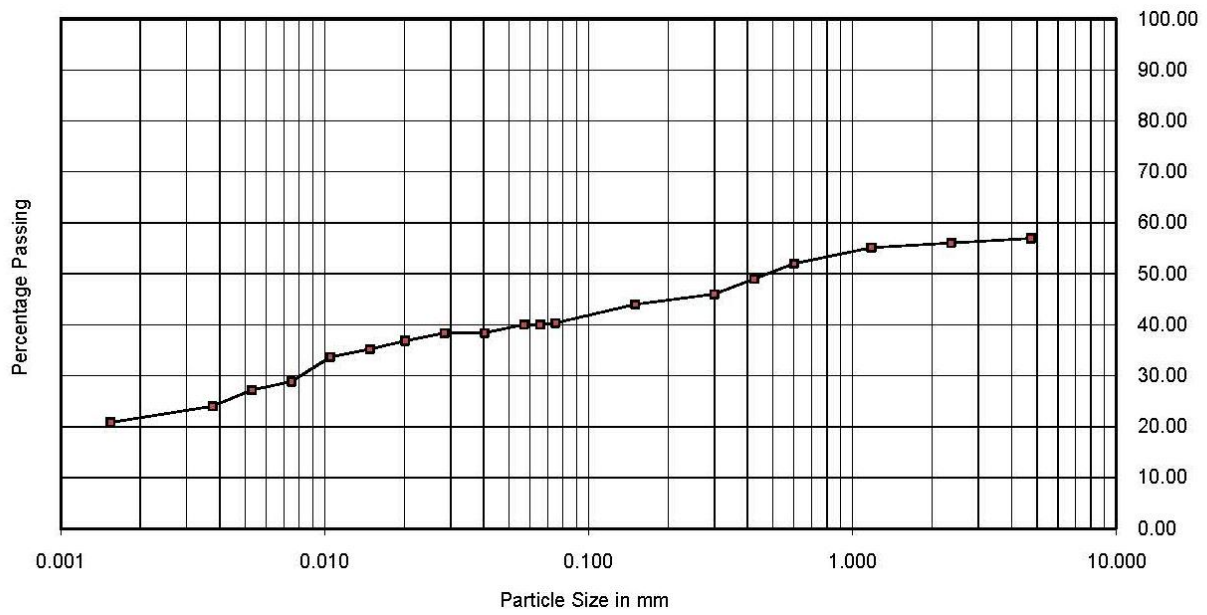
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
2	20.80	19.54	16.56	43.10

Sample No - 3
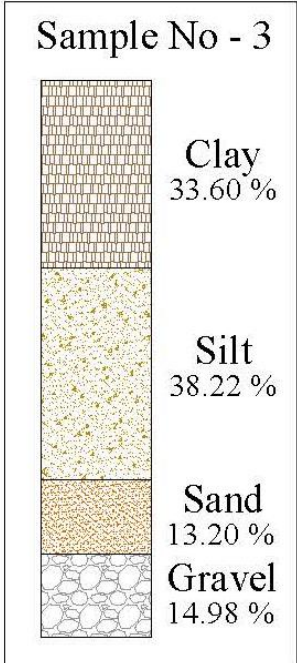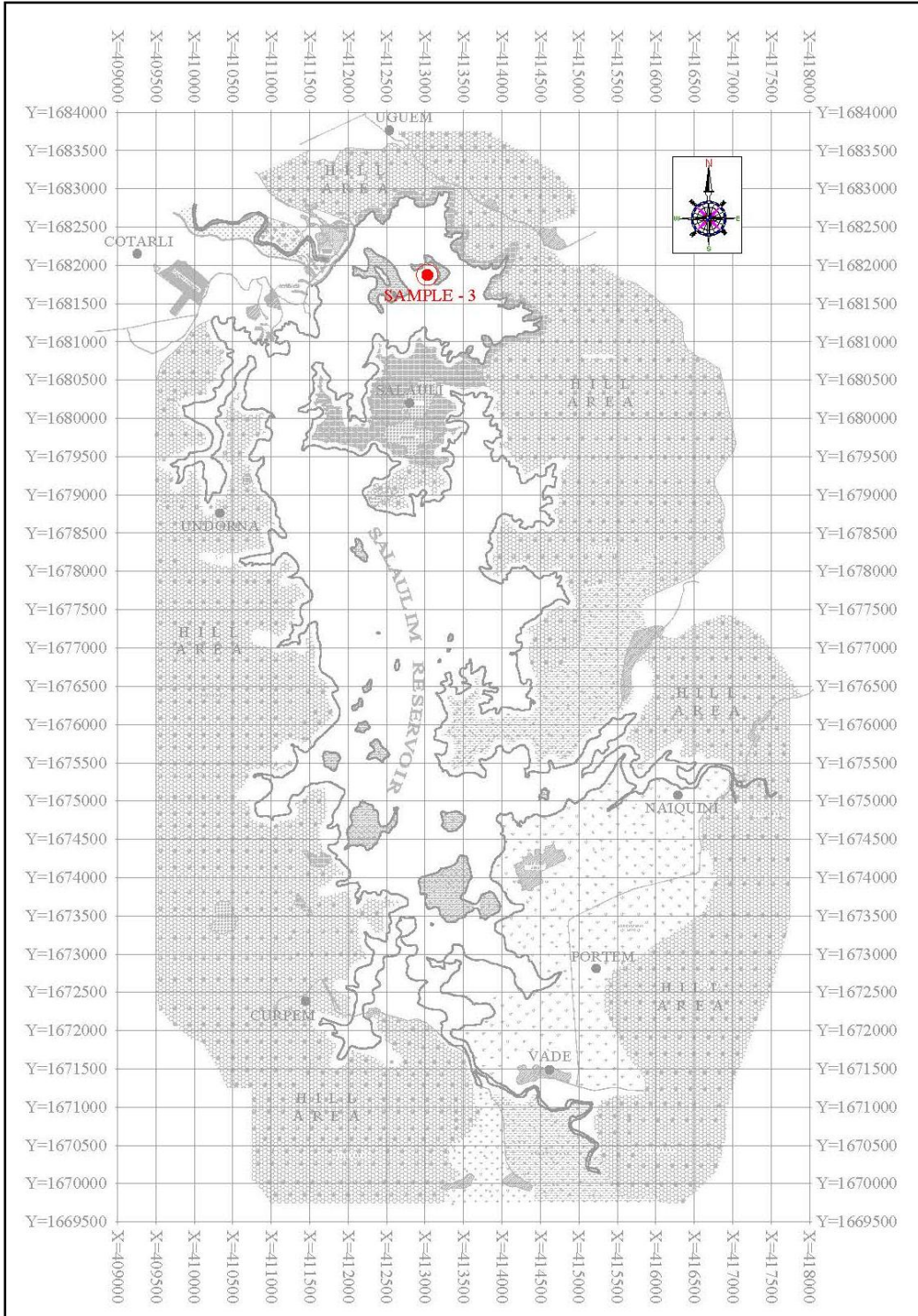
Clay
33.60 %

Silt
38.22 %

Sand
13.20 %

Gravel
14.98 %

GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	3
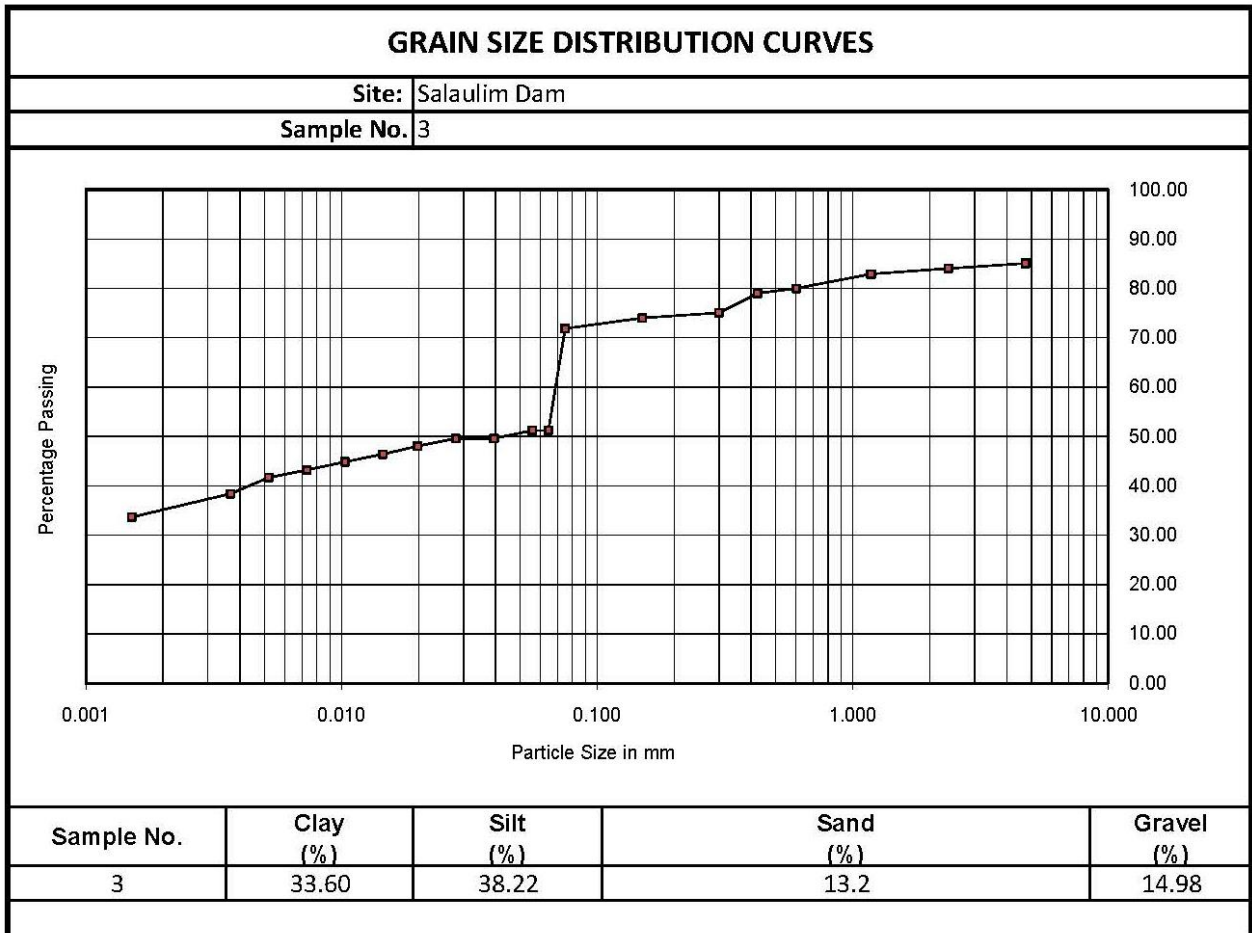
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
3	33.60	38.22	13.2	14.98
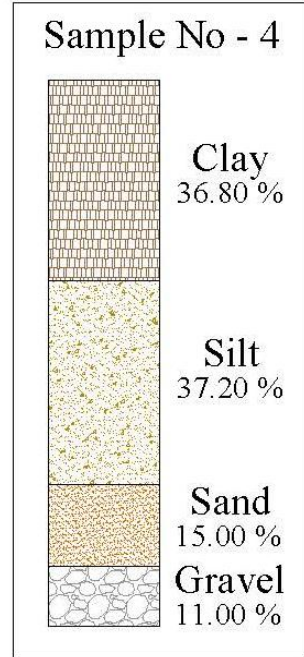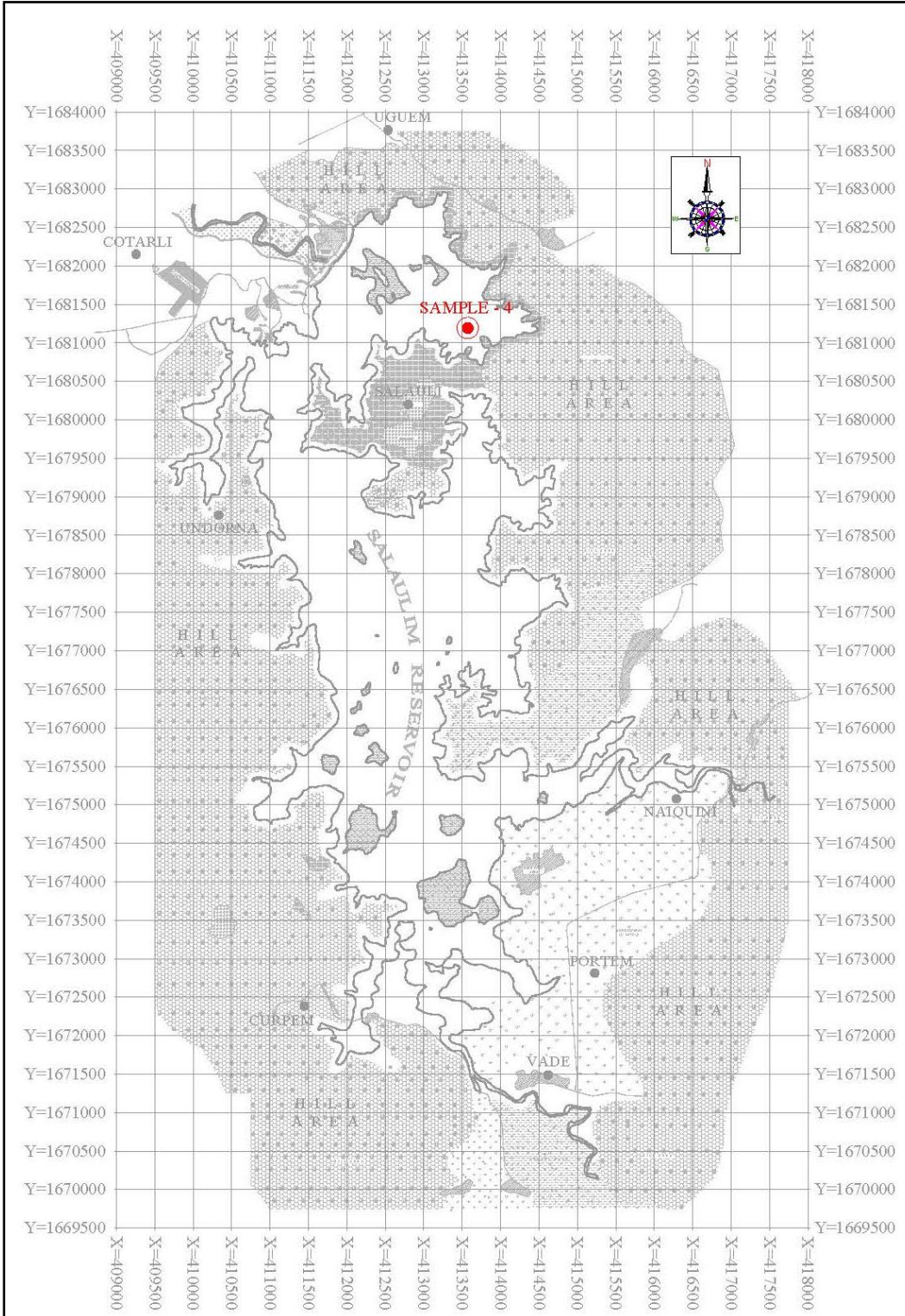
Sample No - 4

Clay
36.80 %

Silt
37.20 %

Sand
15.00 %

Gravel
11.00 %

GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	4
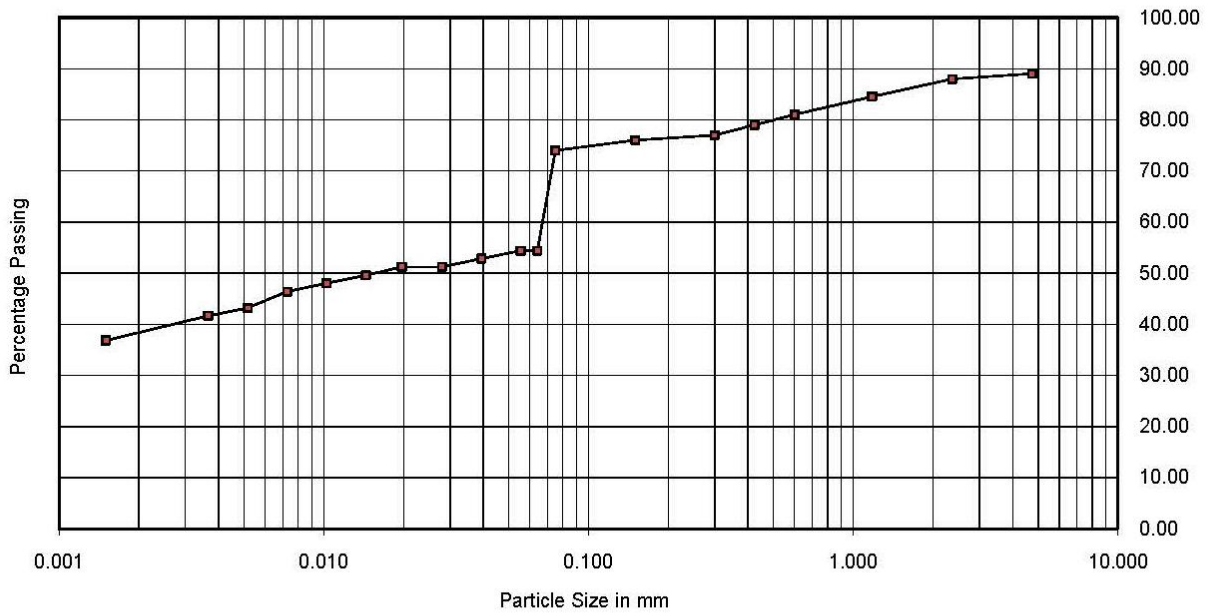
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
4	36.80	37.20	15	11.00
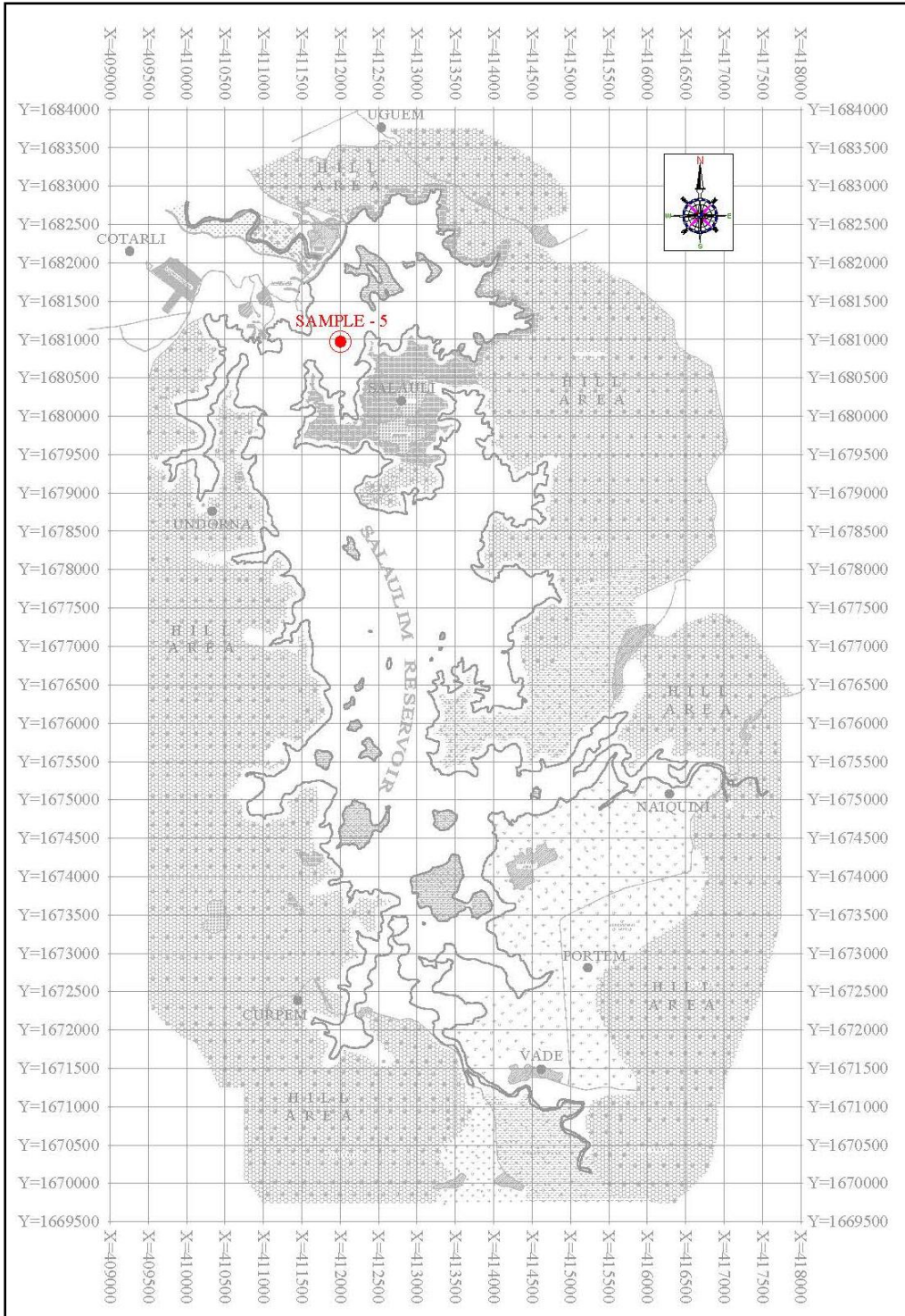
Sample No - 5

Clay
22.40 %

Silt
17.60 %

Sand
21.00 %

Gravel
39.00 %

GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	5
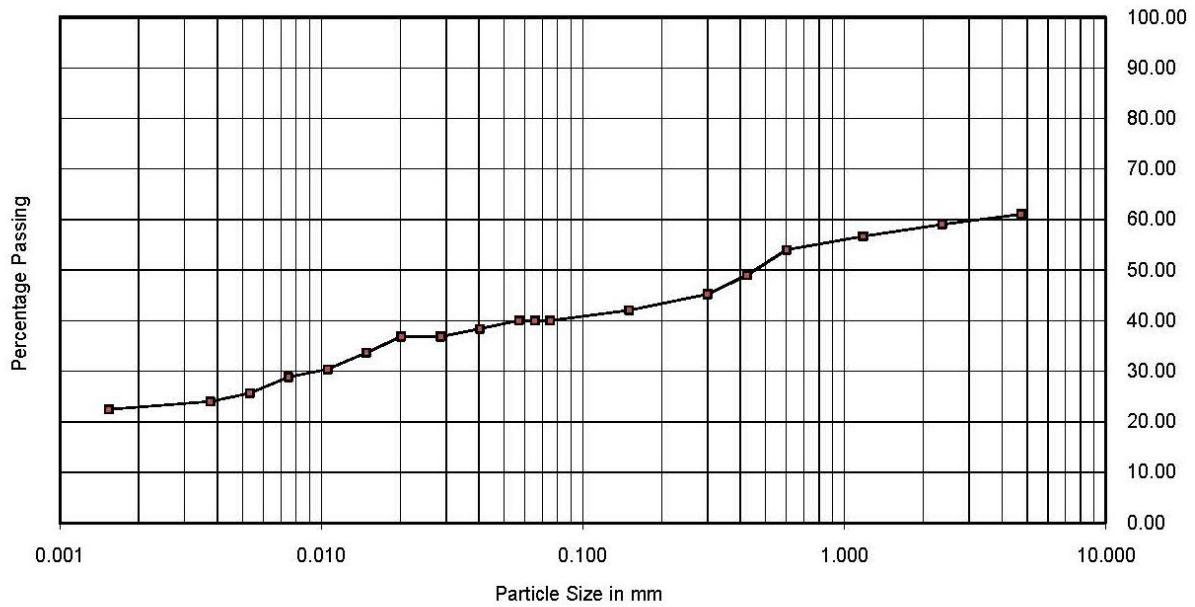
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
5	22.40	17.60	21	39.00
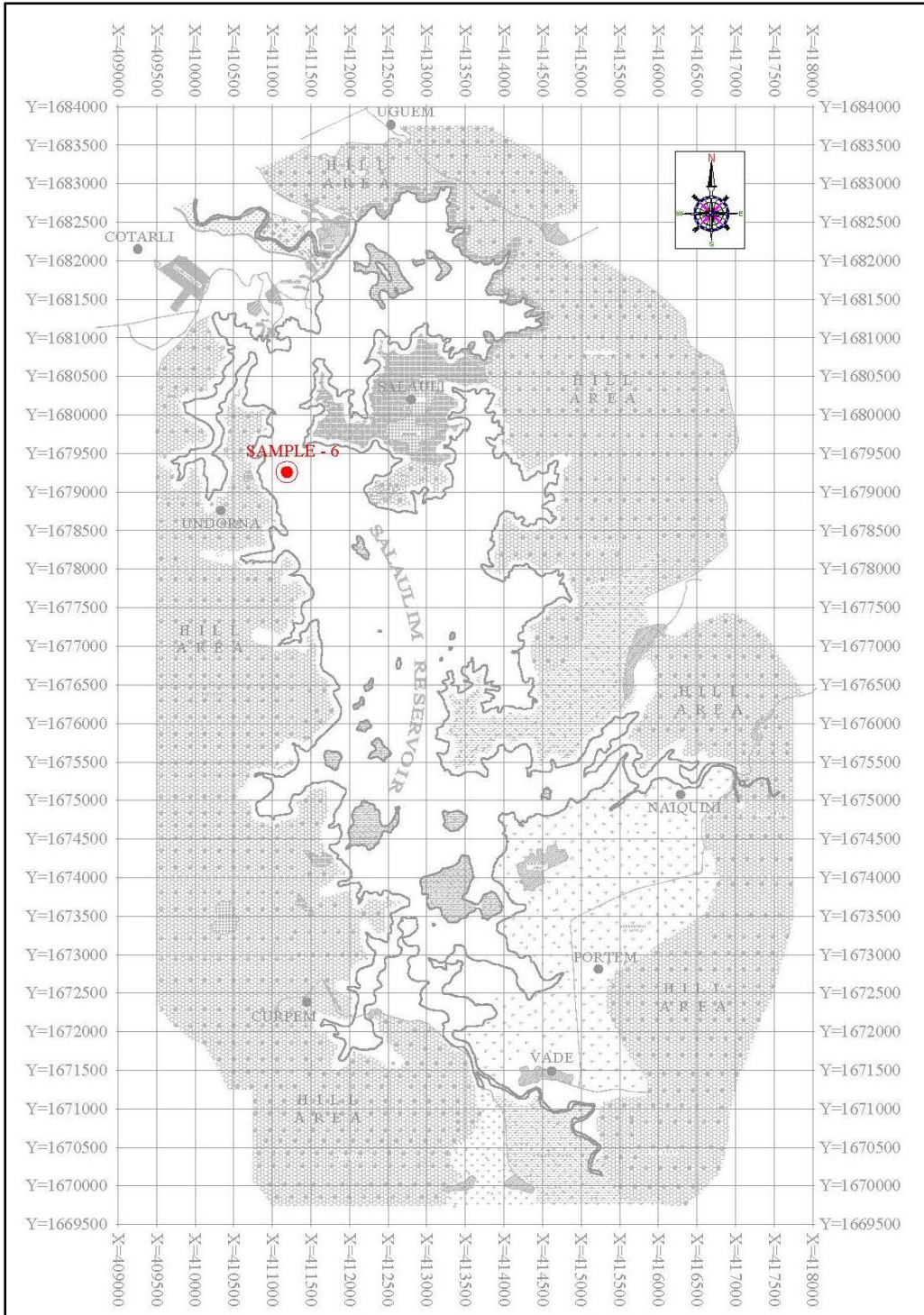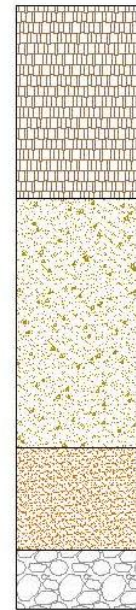
GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	6
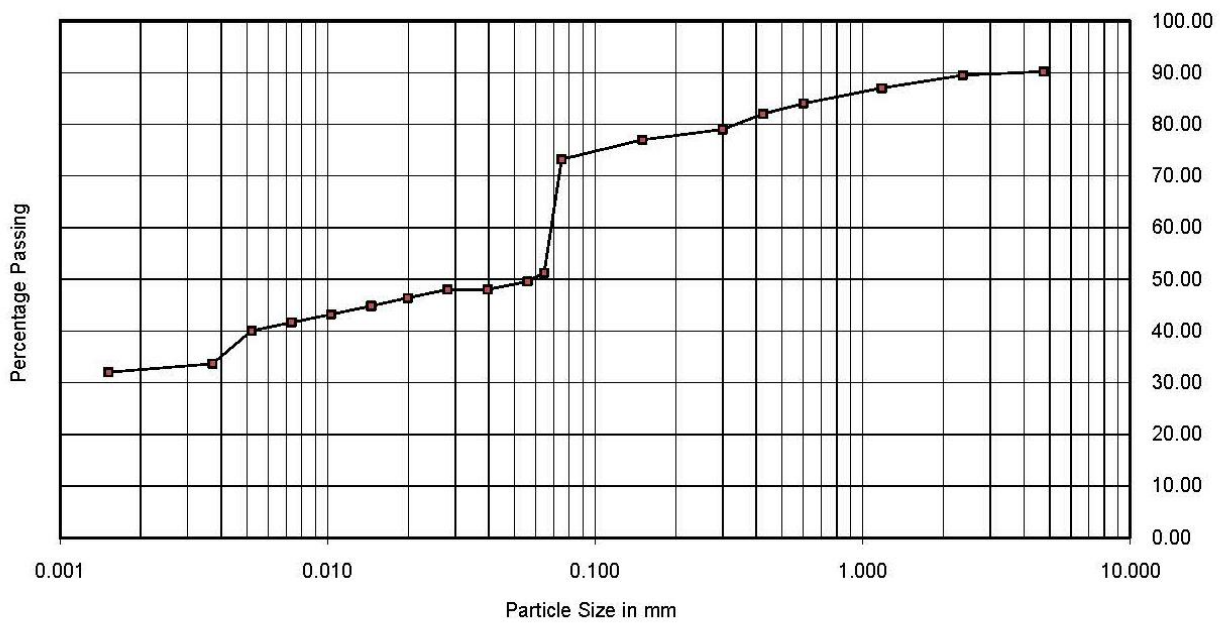
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
6	32.00	41.20	17	9.80

Sample No - 7
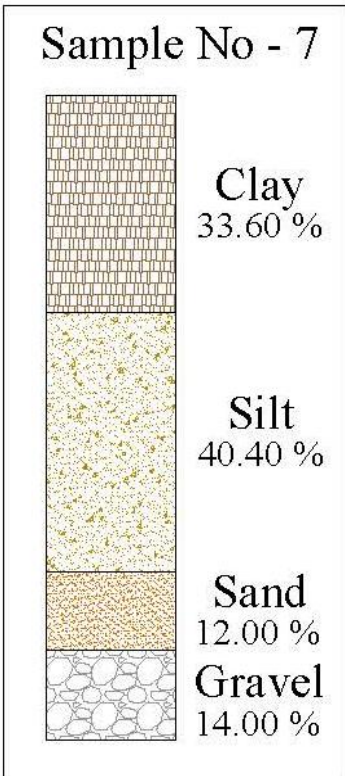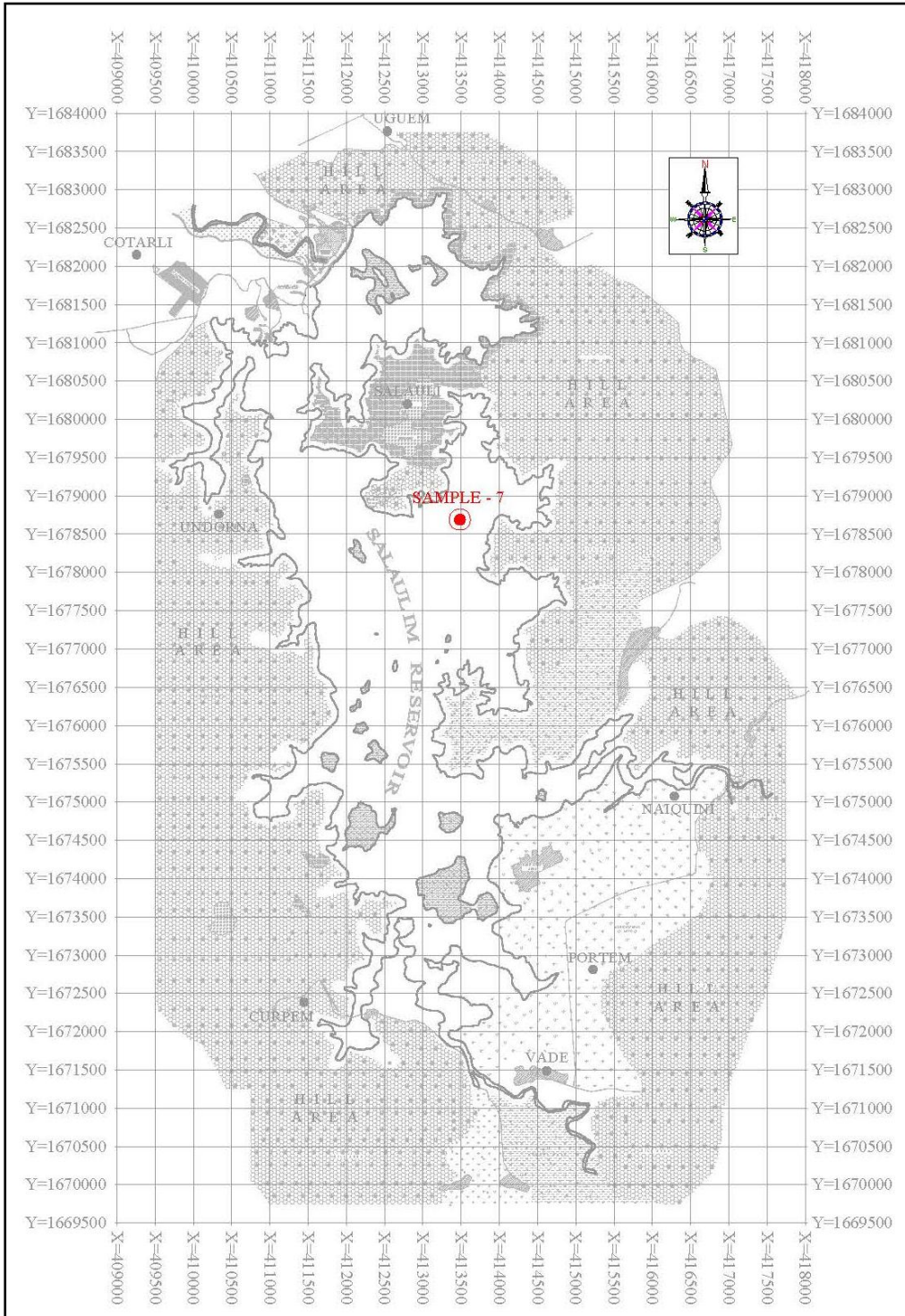
Clay
33.60 %

Silt
40.40 %

Sand
12.00 %

Gravel
14.00 %

GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	7
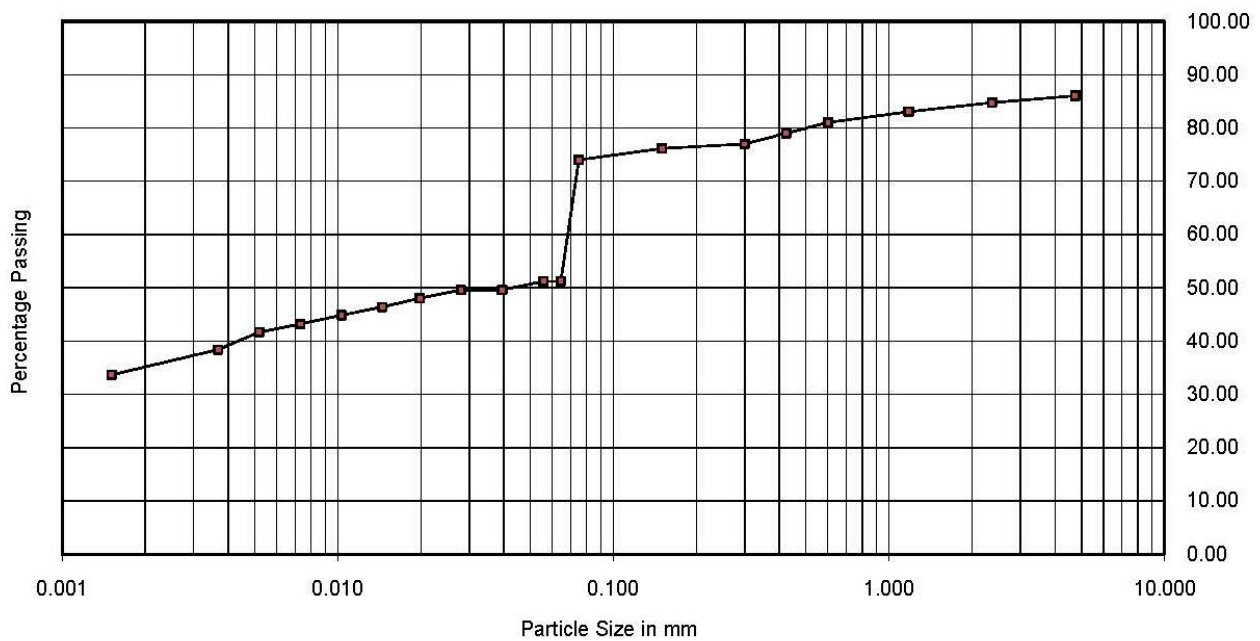
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
7	33.60	40.40	12	14.00

Sample No - 8
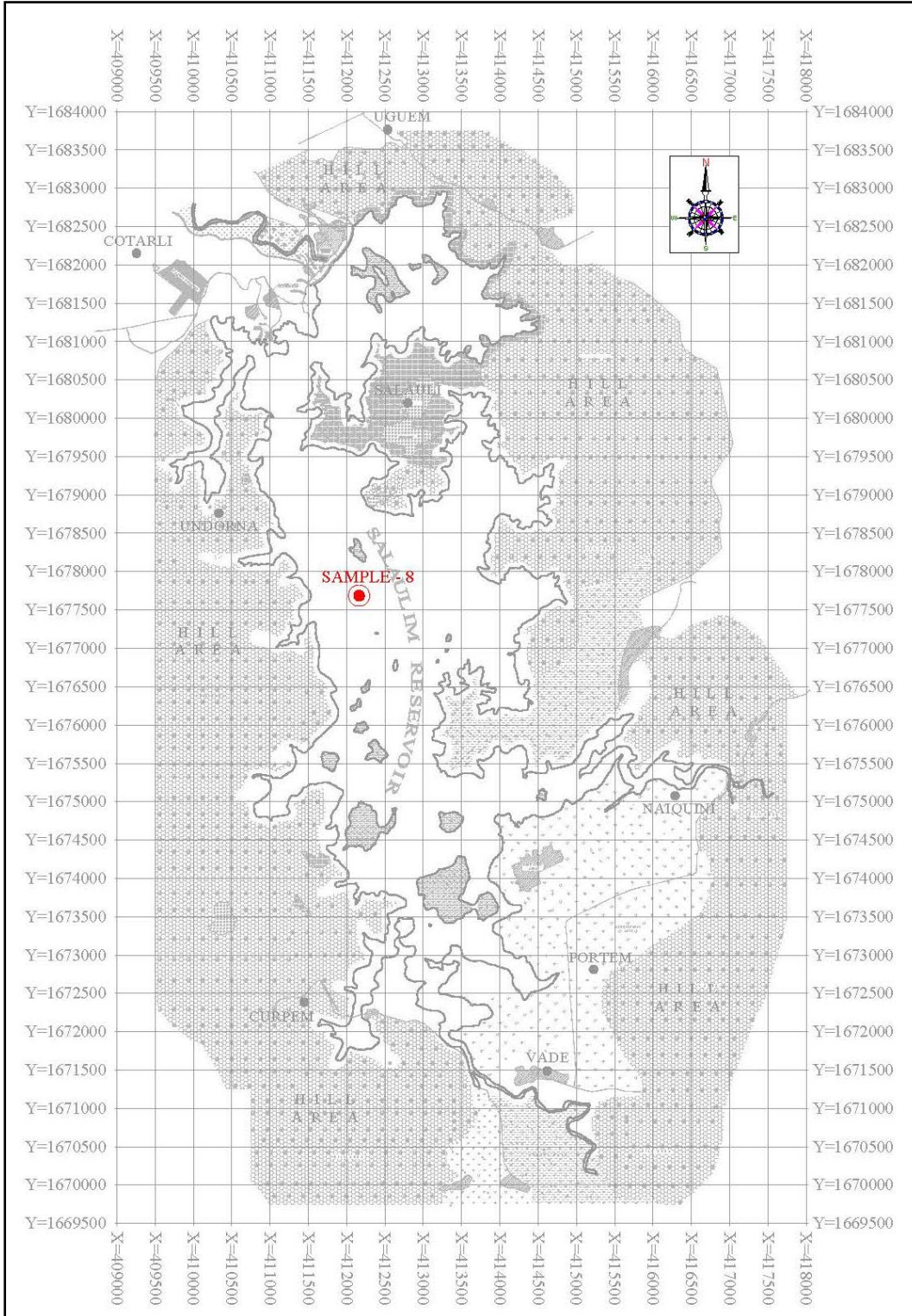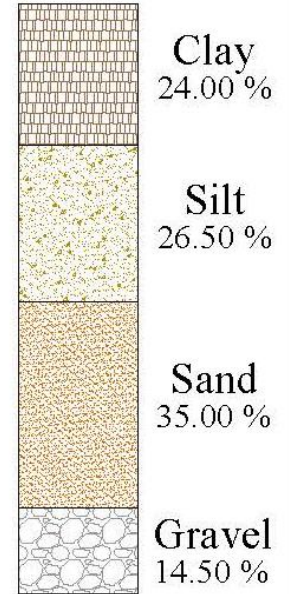
Clay
24.00 %

Silt
26.50 %

Sand
35.00 %

Gravel
14.50 %

GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	8
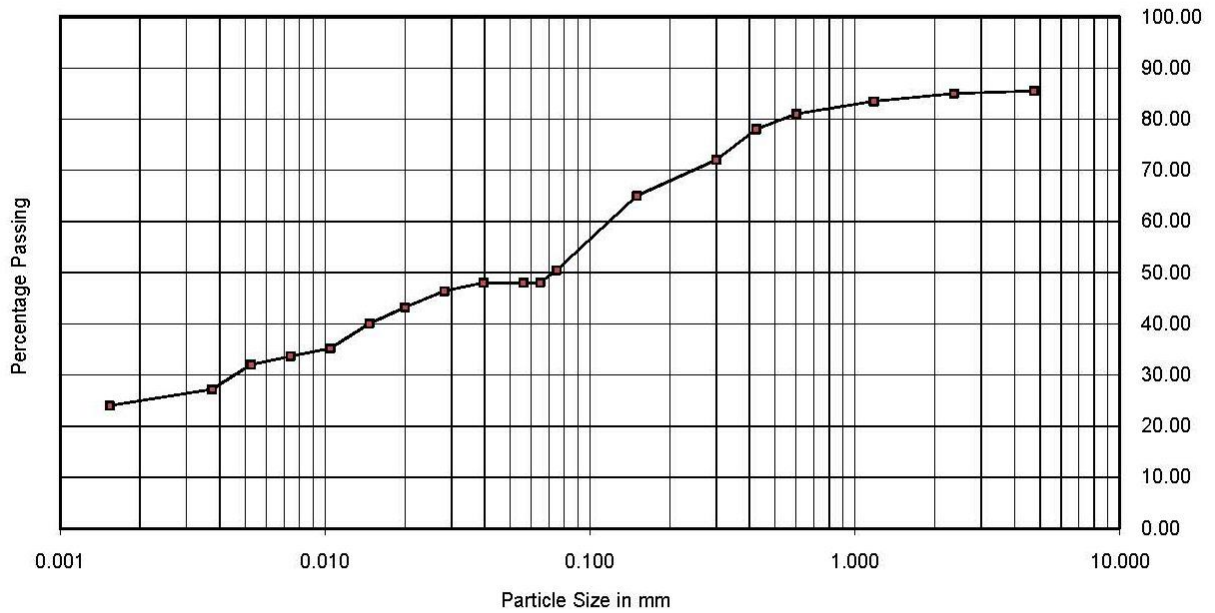
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
8	24.00	26.50	35	14.50

Sample No - 9
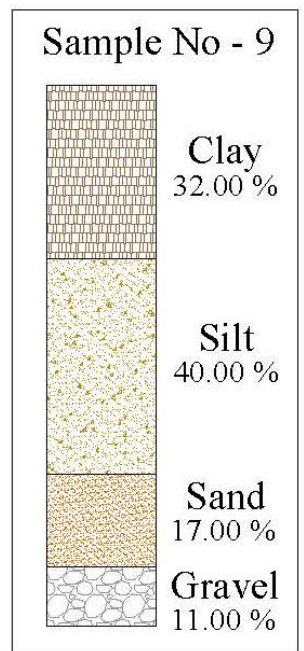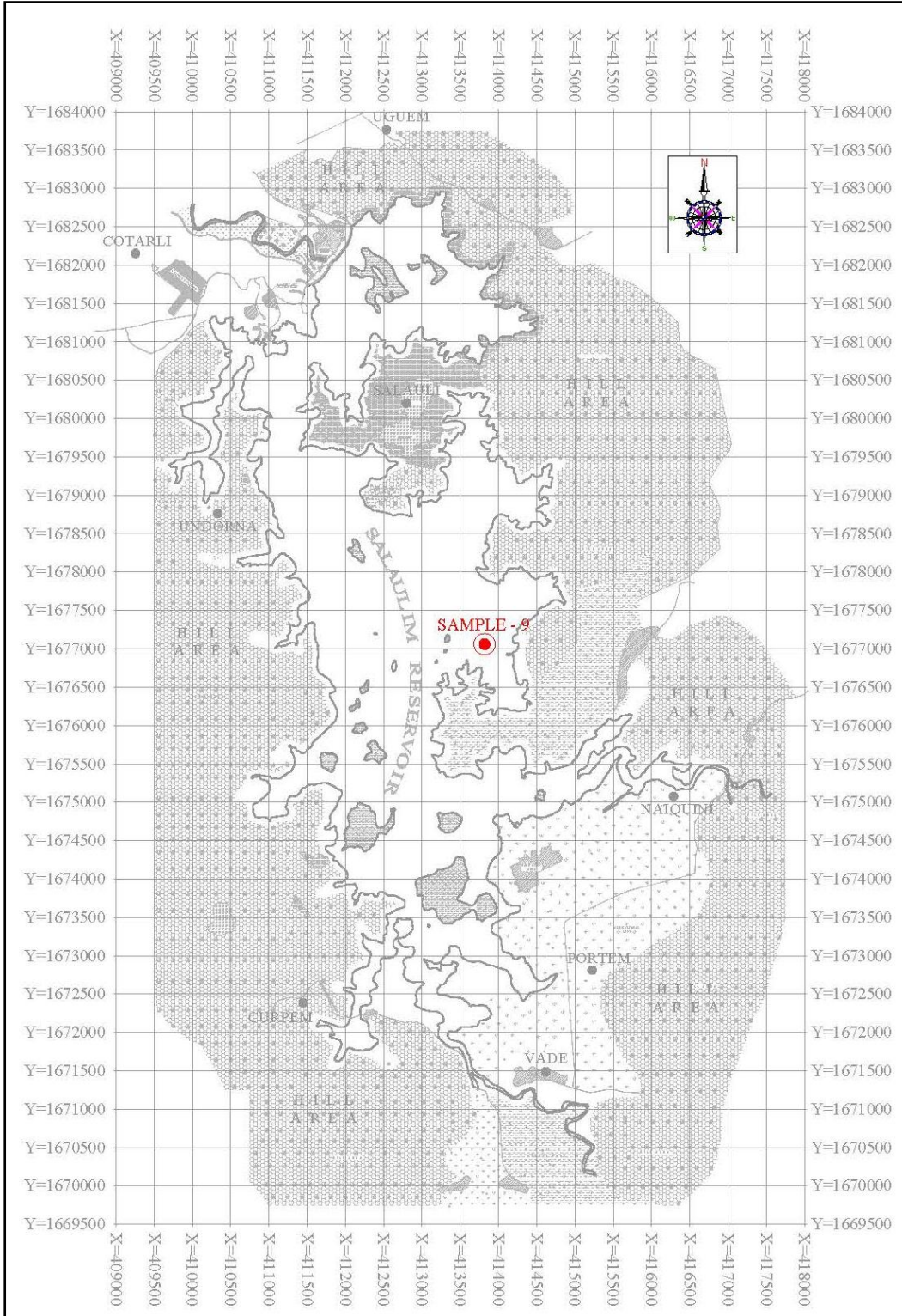
Clay
32.00 %

Silt
40.00 %

Sand
17.00 %

Gravel
11.00 %

SAMPLE - 9

GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	9
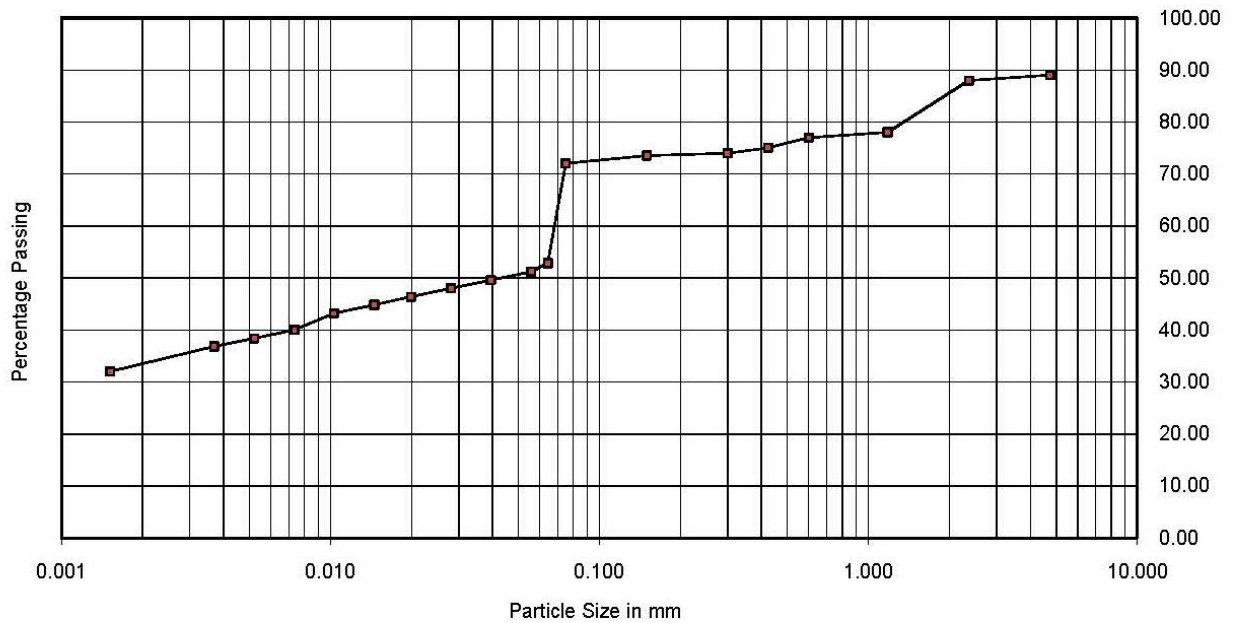
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
9	32.00	40.00	17	11.00

Sample No - 10
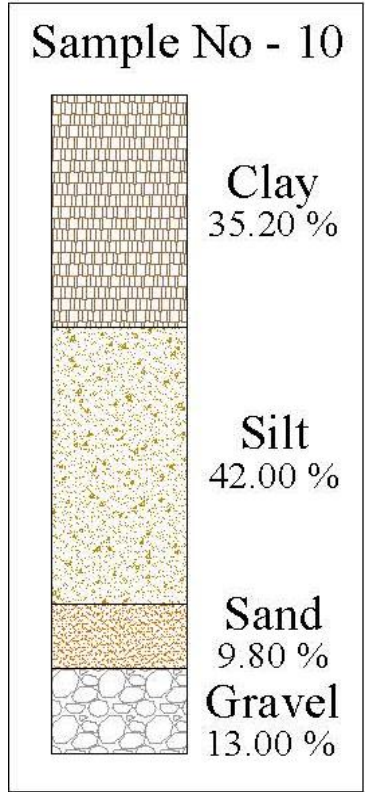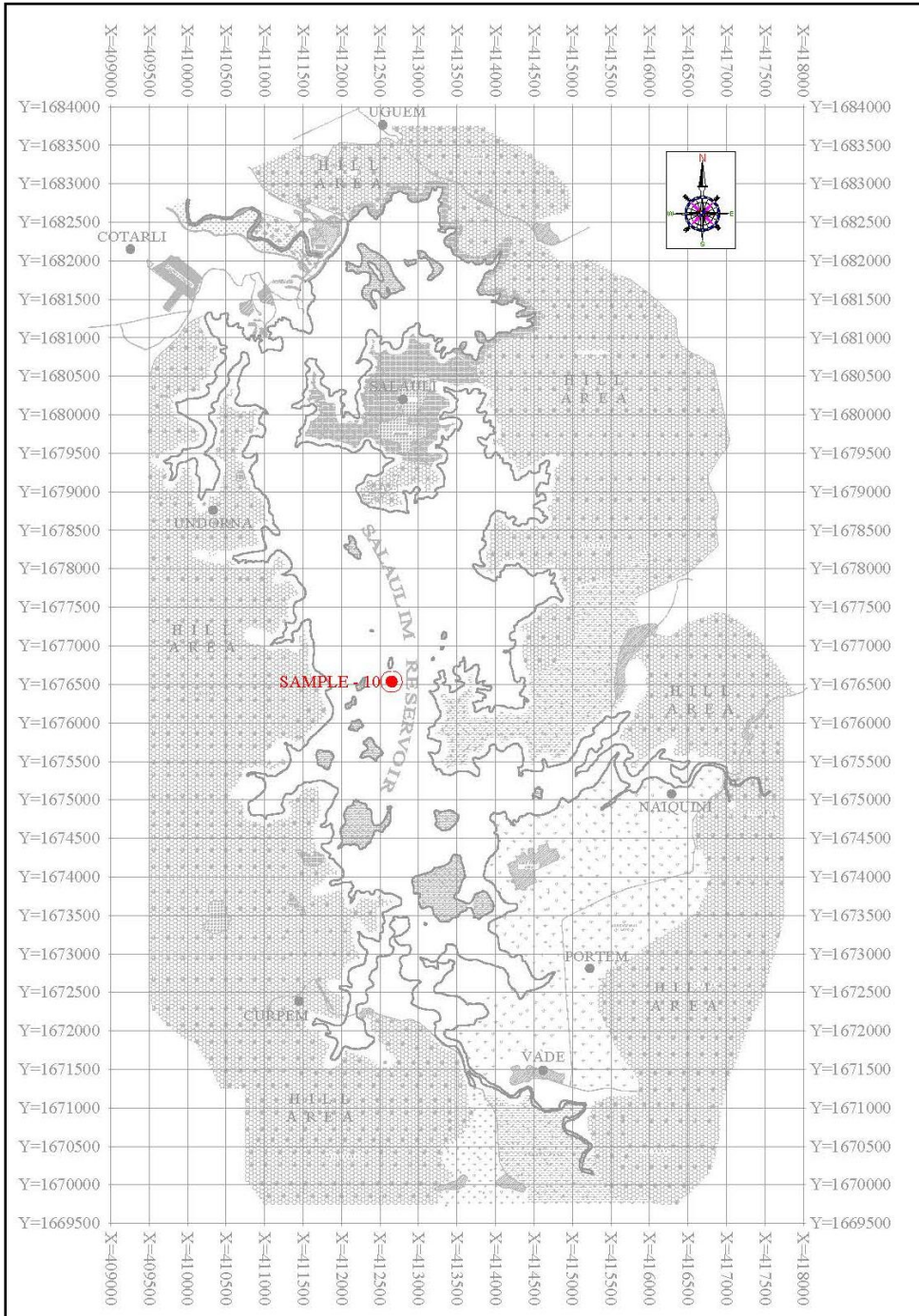
Clay
35.20 %

Silt
42.00 %

Sand
9.80 %

Gravel
13.00 %

GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	10
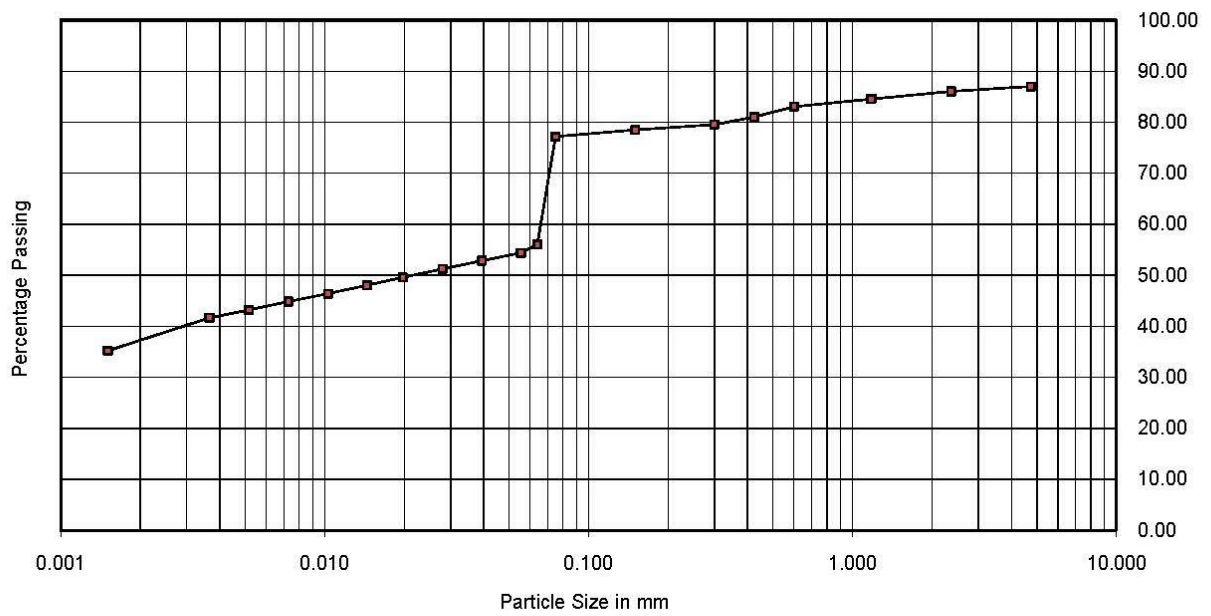
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
10	35.20	42.00	9.8	13.00

Sample No - 11
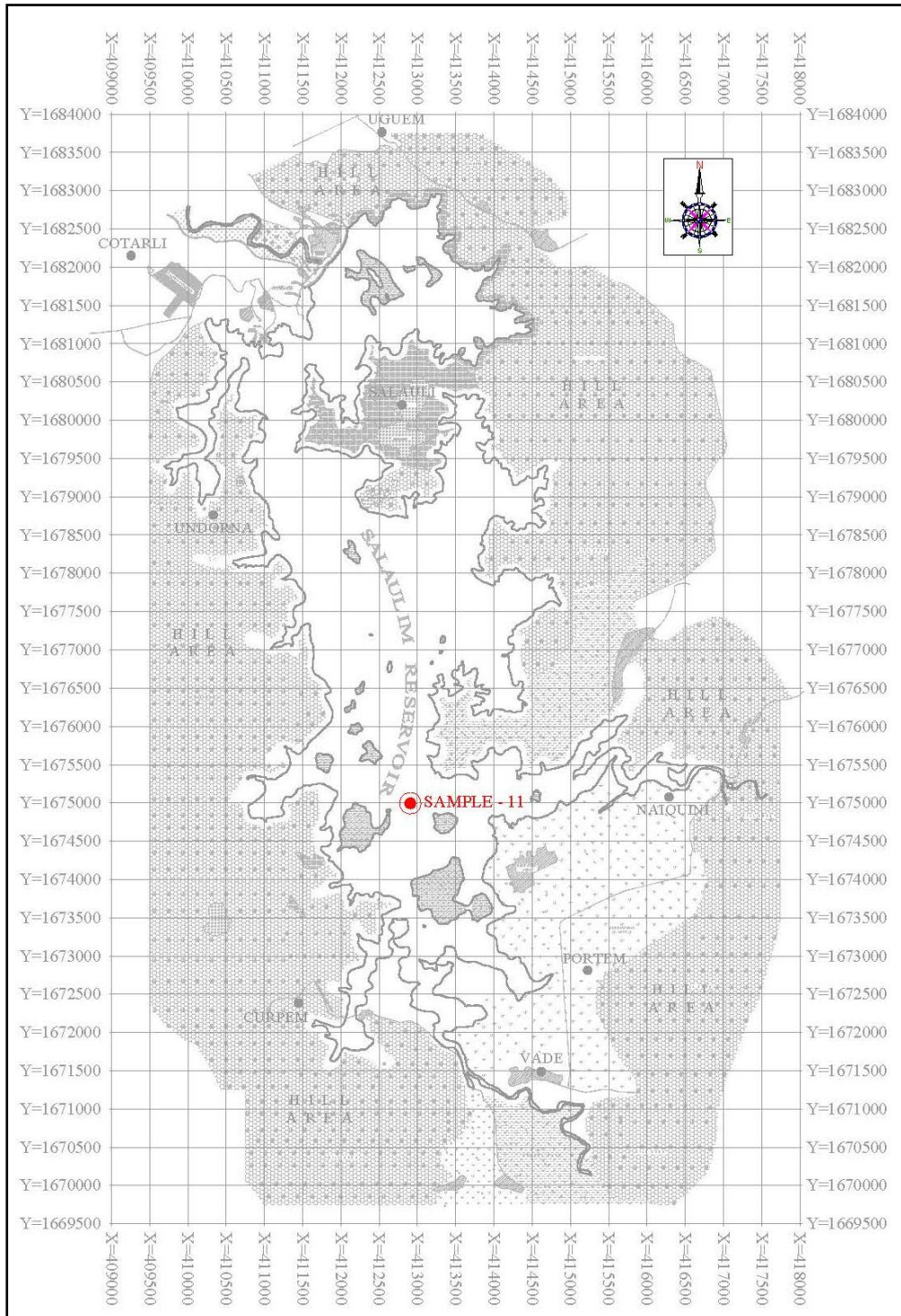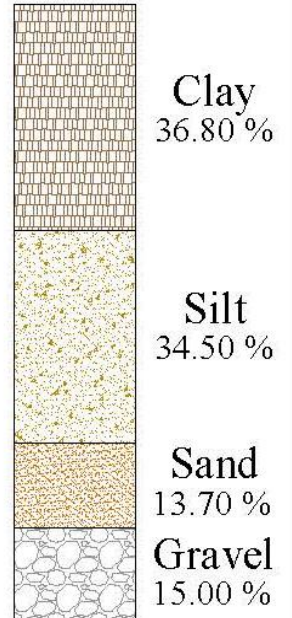
Clay
36.80 %

Silt
34.50 %

Sand
13.70 %

Gravel
15.00 %

GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	11
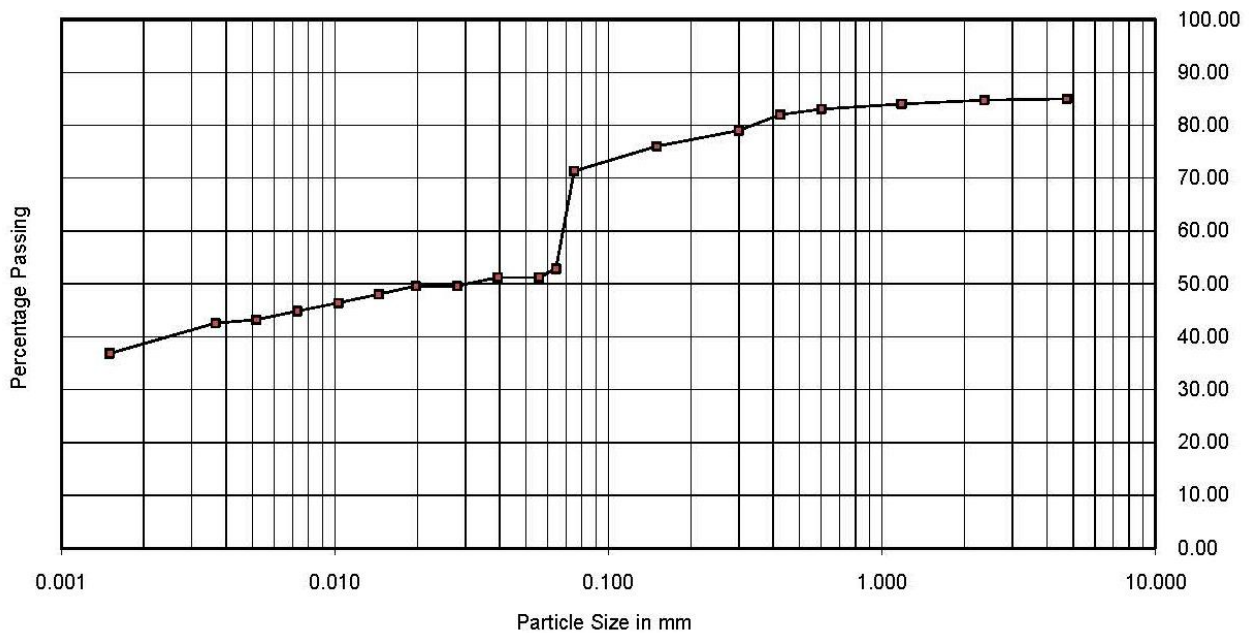
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
11	36.80	34.50	13.7	15.00
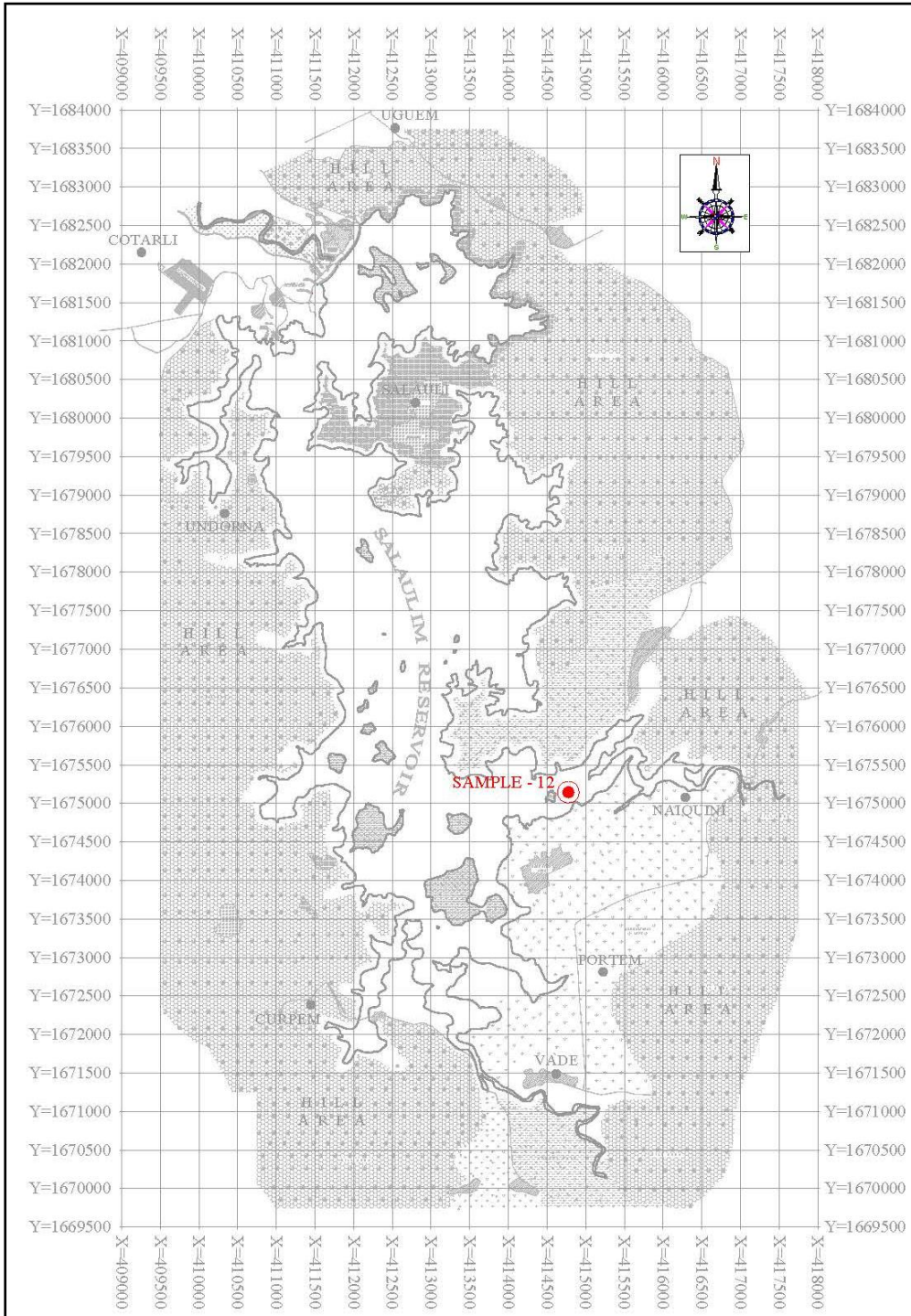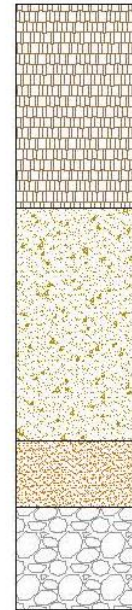
GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	12
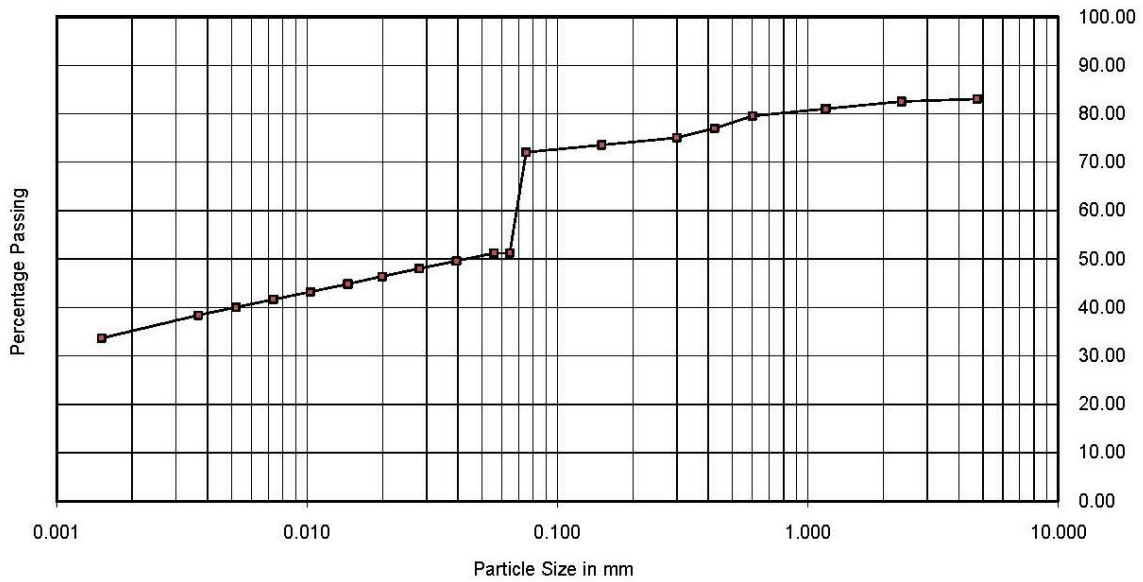
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
12	33.60	38.40	11	17.00
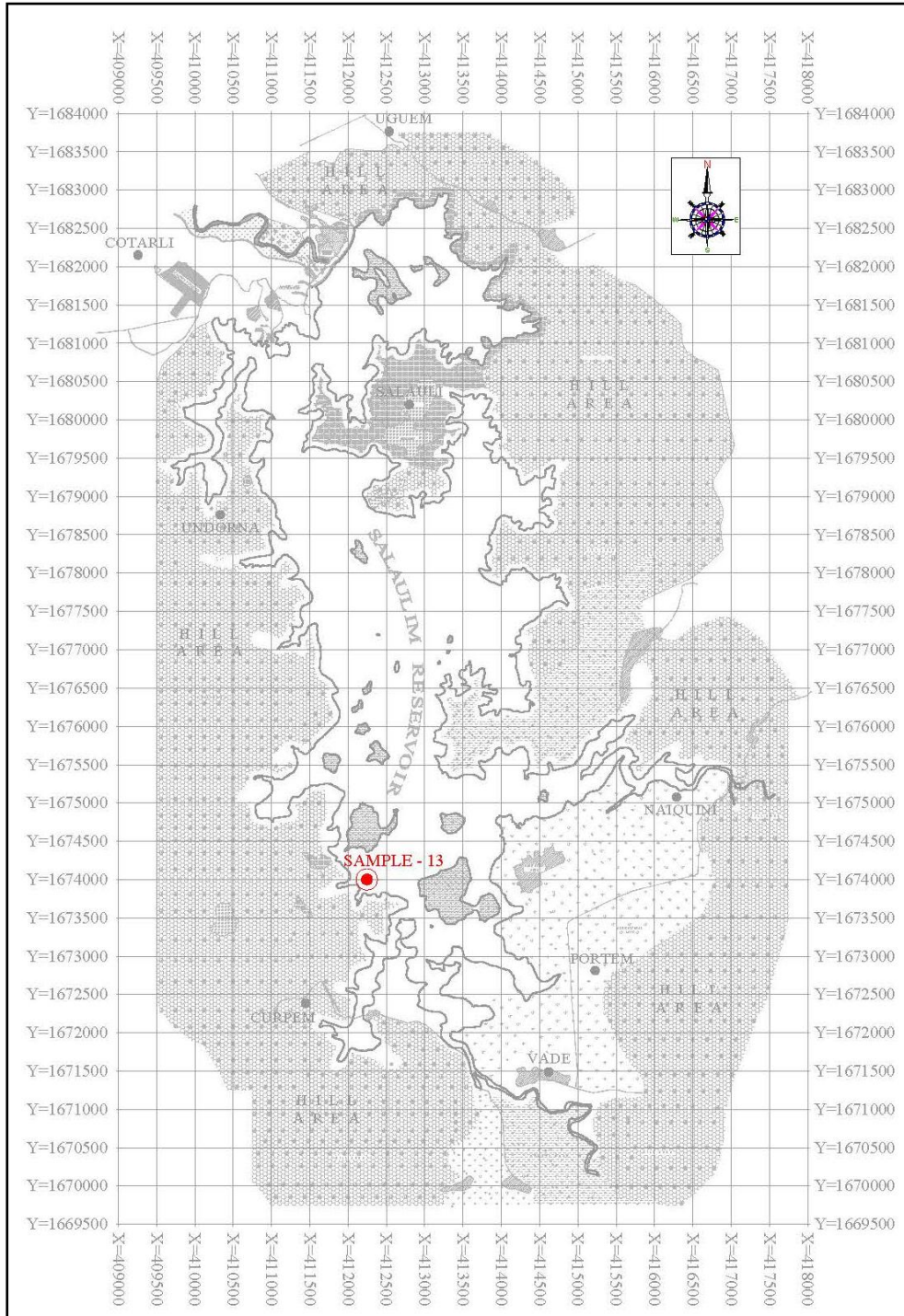
Sample No - 13
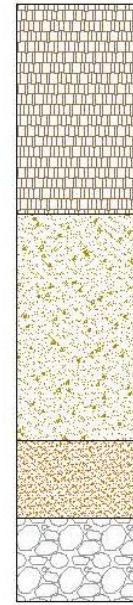
Clay
35.20 %

Silt
37.80 %

Sand
13.00 %

Gravel
14.00 %

GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	13
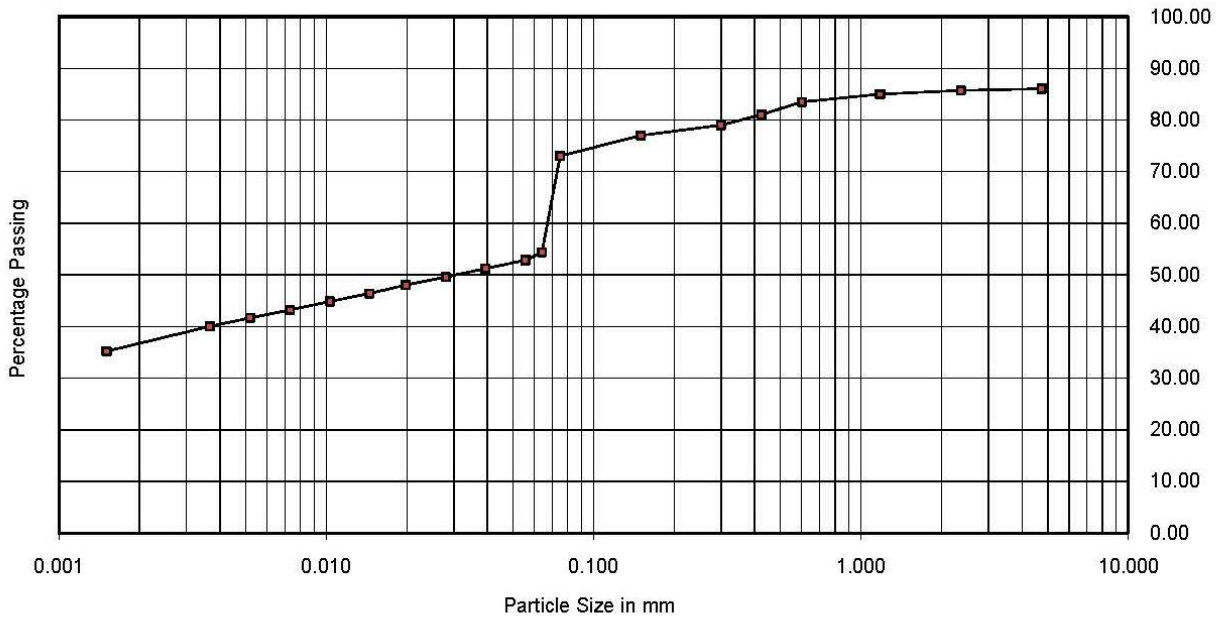
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
13	35.20	37.80	13	14.00

Sample No - 14
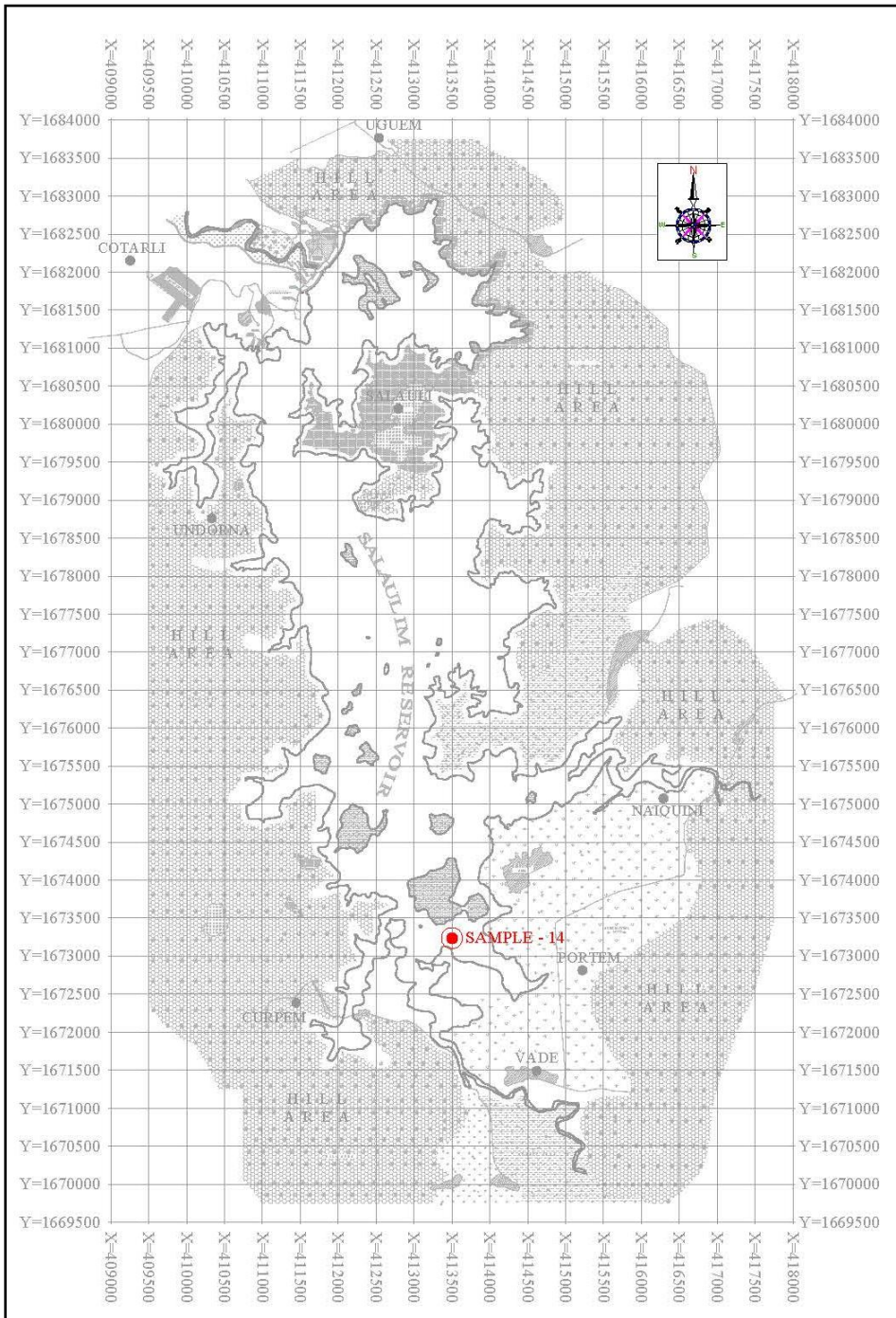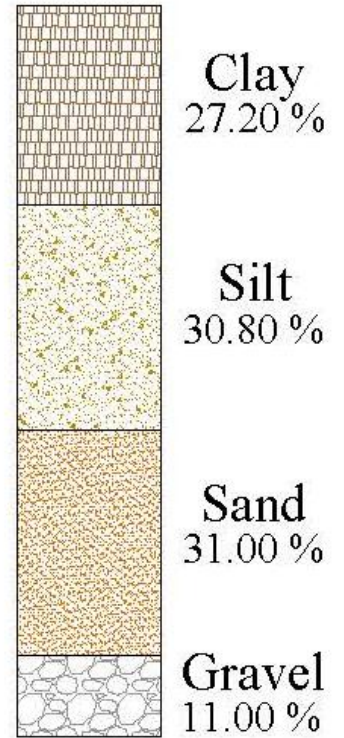
Clay
27.20 %

Silt
30.80 %

Sand
31.00 %

Gravel
11.00 %

GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	14
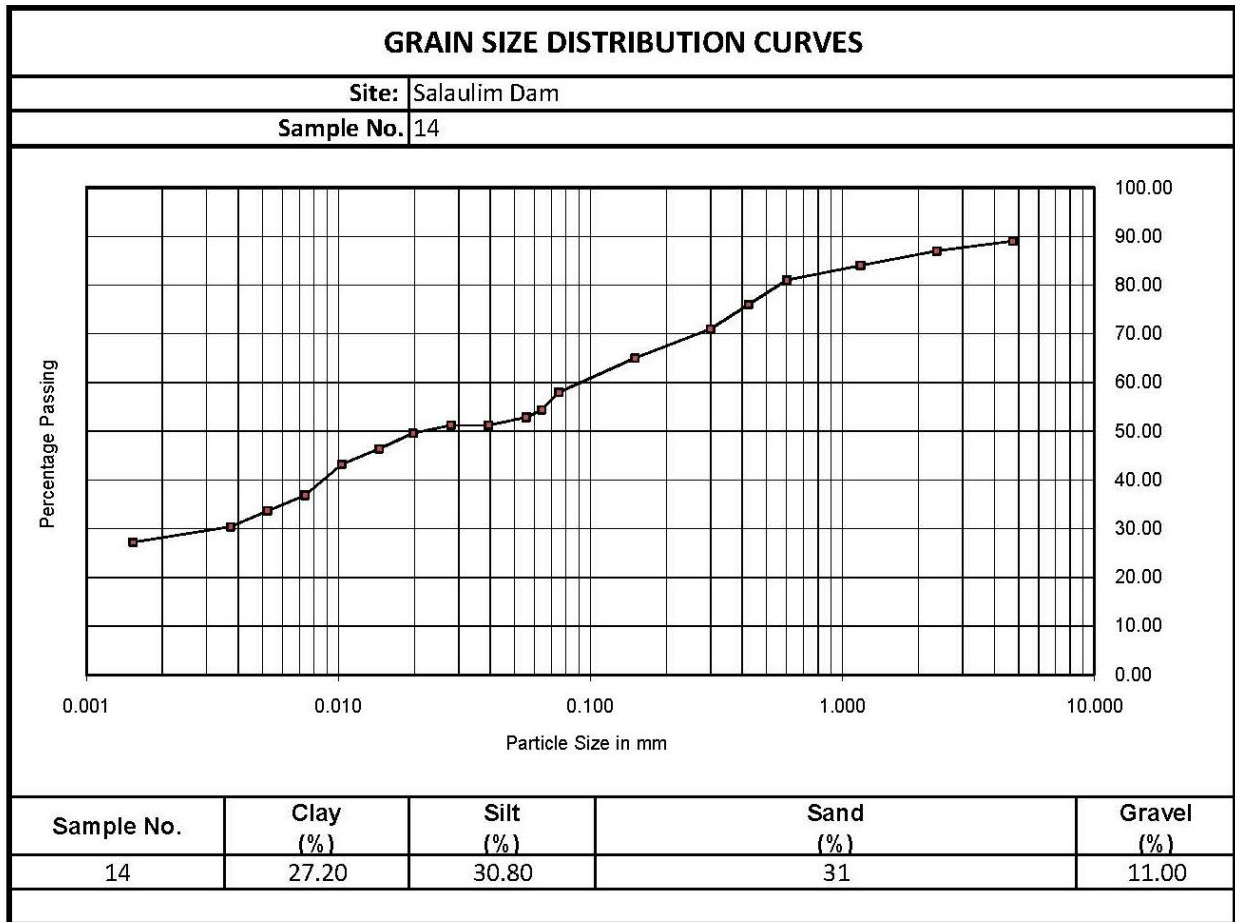
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
14	27.20	30.80	31	11.00
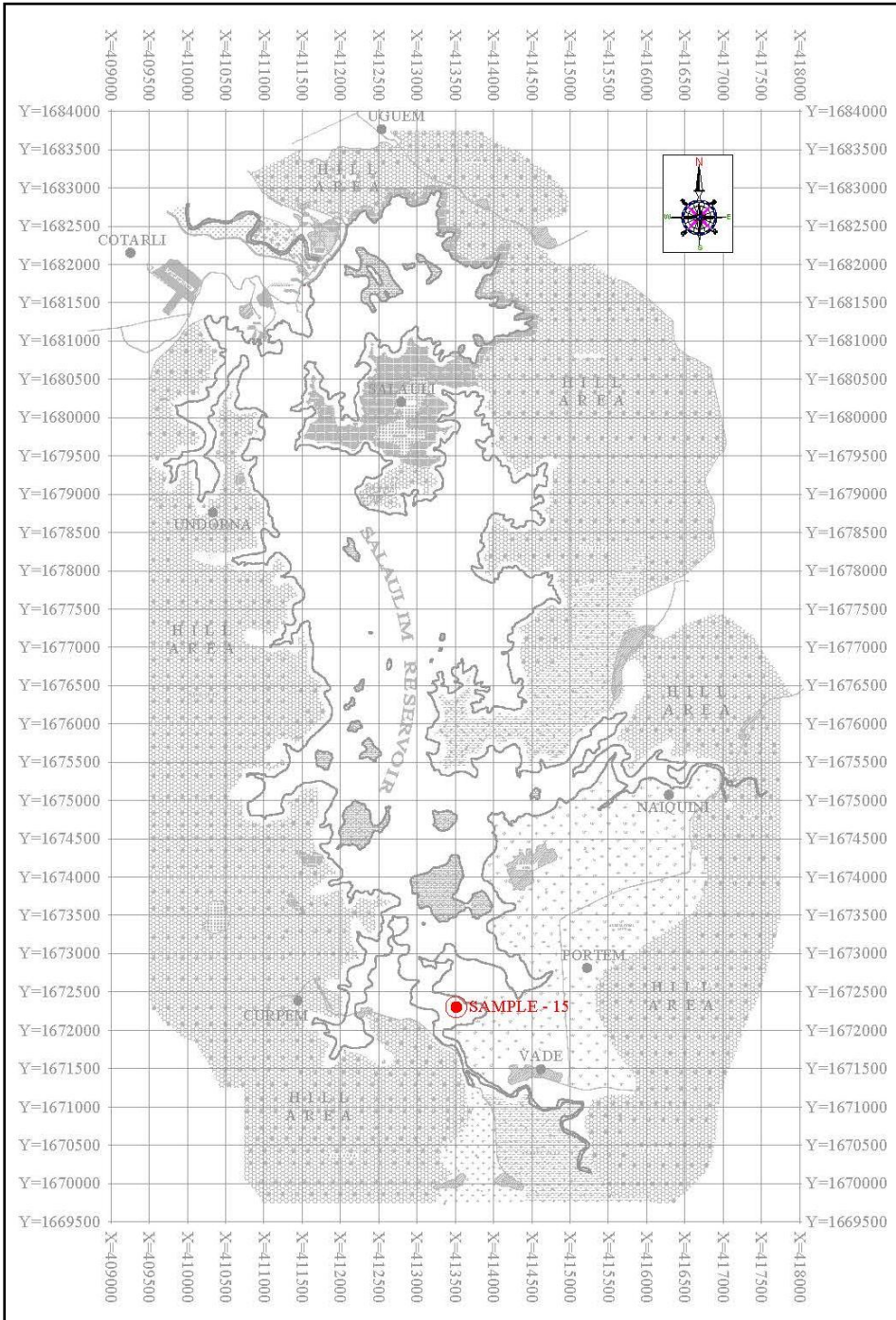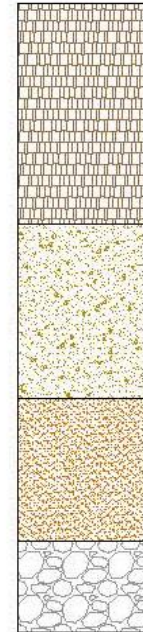
Sample No - 15

Clay
35.20 %

Silt
27.56 %

Sand
22.70 %

Gravel
14.54 %

GRAIN SIZE DISTRIBUTION CURVES

Site:	Salaulim Dam
Sample No.	15
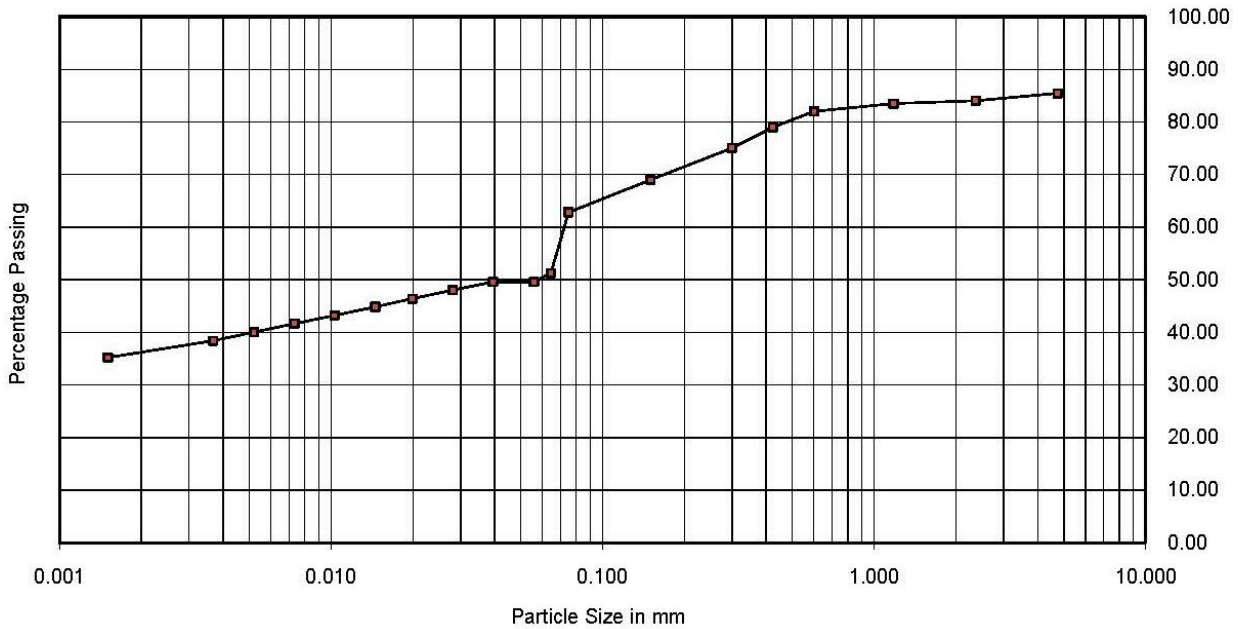
Sample No.	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
15	35.20	27.56	22.7	14.54

13.3 Water Sample Report:-

				SITE: SALAULIM DAM			
				TEST RESULTS			
Sl. No.	Sample No.	Latitude (N)	Longitude (E)	Depth (m)	pH Value	Sulphate (ppm)	Chloride (ppm)
1	1	15°12'46.13"	74°10'47.21"	6.20	7.15	70.00	50.00
2	2	15°13'3.74"	74°11'17.17"	10.40	7.14	80.00	10.00
3	3	15°12'41.22"	74°11'24.99"	9.73	6.82	60.00	10.00
4	4	15°12'19.10"	74°11'43.29"	7.50	6.98	40.00	10.00
5	5	15°12'11.76"	74°10'50.70"	12.22	7.16	90.00	10.00
6	6	15°11'15.87"	74°10'23.60"	14.90	6.90	50.00	10.00
7	7	15°10'57.62"	74°11'40.64"	14.30	6.92	60.00	10.00
8	8	15°10'24.75"	74°10'56.44"	9.98	6.89	50.00	10.00
9	9	15°10'4.59"	74°11'52.00"	12.60	6.99	40.00	10.00
10	10	15°9'47.46"	74°11'12.98"	9.21	6.72	50.00	10.00
11	11	15°8'57.27"	74°11'21.74"	7.50	6.86	40.00	10.00
12	12	15°9'2.34"	74°12'24.36"	4.70	6.99	60.00	10.00
13	13	15°8'24.88"	74°10'59.72"	3.20	6.92	50.00	10.00
14	14	15°8'0.06"	74°11'41.92"	3.40	7.12	60.00	40.00
15	15	15°7'29.74"	74°11'42.35"	3.20	7.04	70.00	10.00

CROSS SECTIONS (v)

This section has been analyzed the cross sectional drawings etc.

14.0 Cross Sectional plan near Chainage (-) 500.00 m to 2000.00m:-
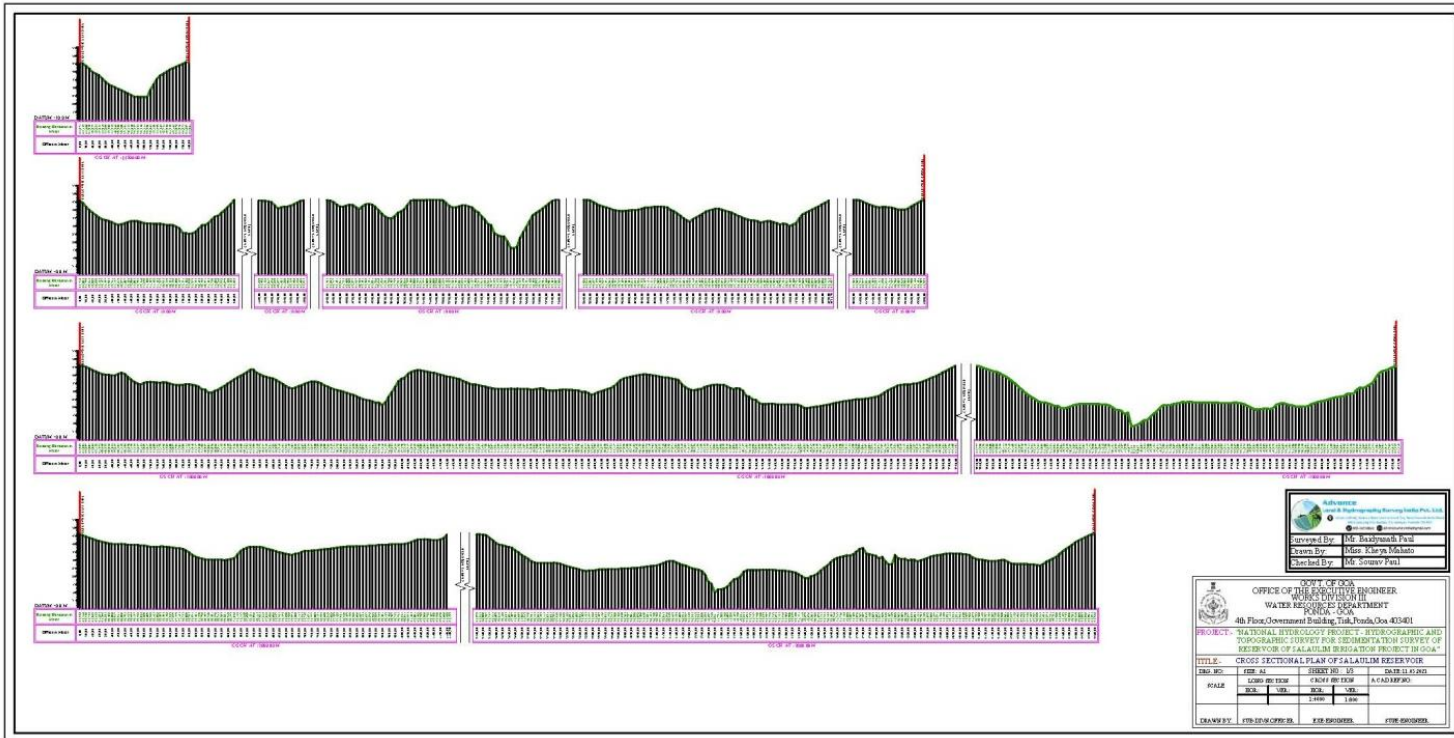
Figure 12-Cross Sectional plan near Chainage (-) 500.00 m to 2000.00m

14.1 Cross Sectional plan near Chainage 3000.00 m to 6000.00m:-
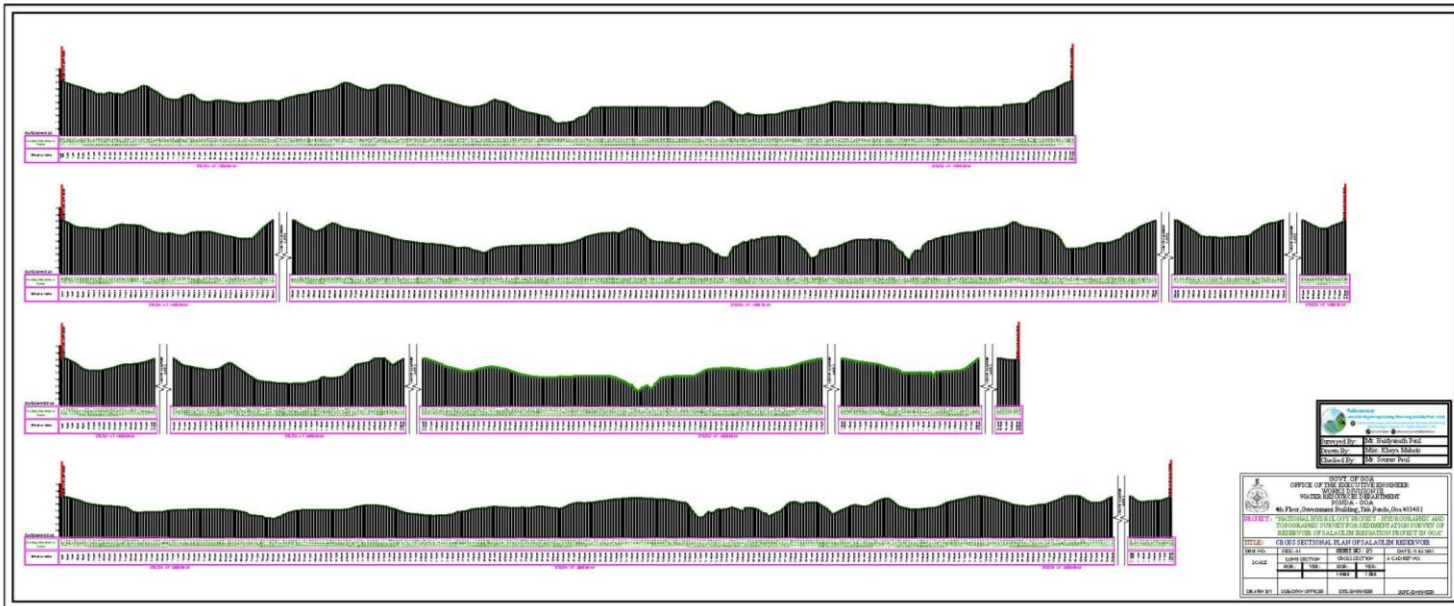
Figure 13-Cross Sectional plan near Chainage 3000.00 m to 6000.00m

14.2 Cross Sectional plan near Chainage 7000.00 m to 10000.00m:-
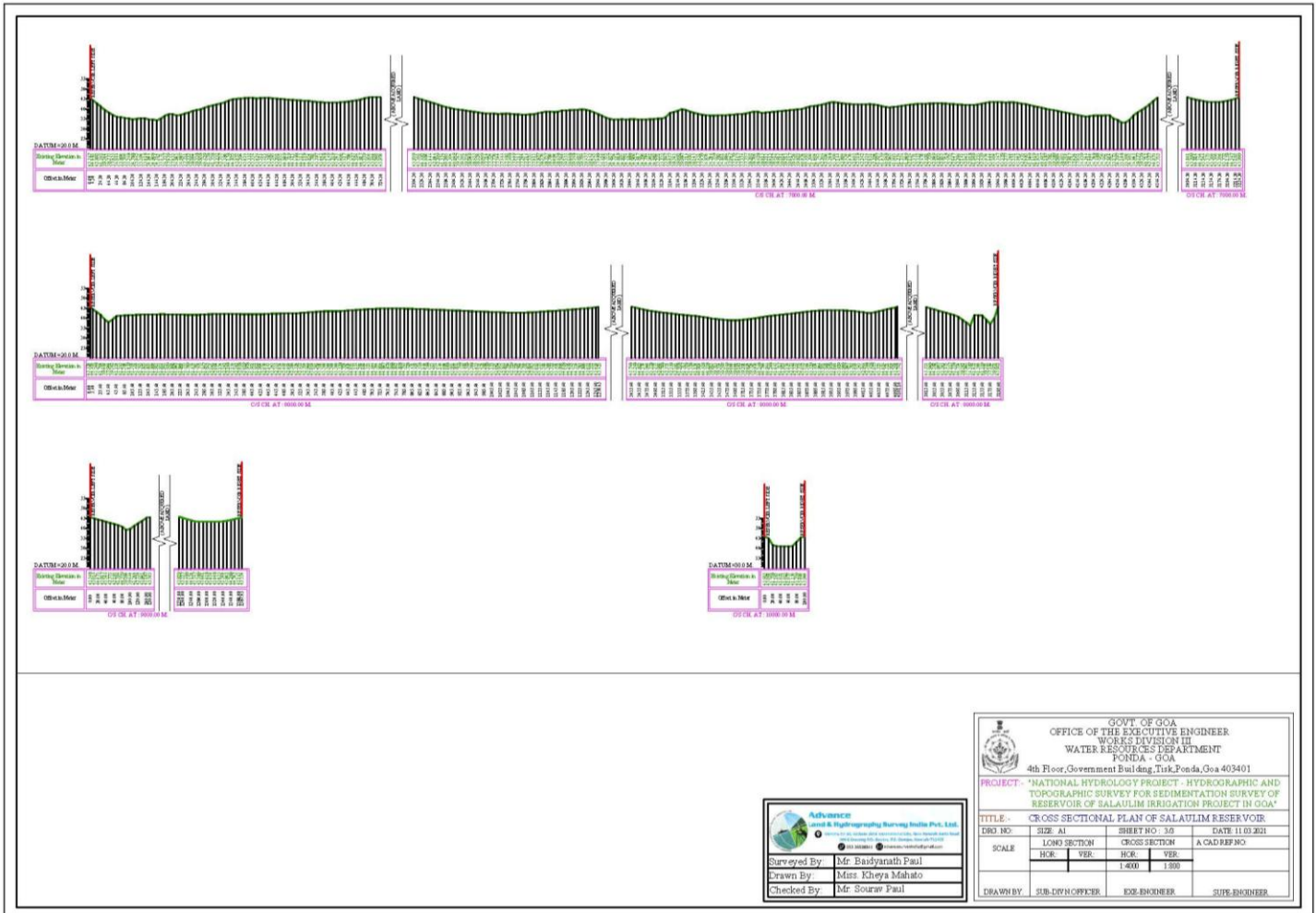
Figure 14-Cross Sectional plan near Chainage 7000.00 m to 10000.00m

L- SECTION (vi)

This section has been analyzed longitudinal section drawings

15.0 Long Sectional plan of Salaulim Dam:-

Figure 15-Long section of Salaulim dam

VERTICAL SEDIMENT DISTRIBUTION (vii)

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

Table-VIII

ZONE	Dead storage	Live Storage	Overall
(Capacity in Salaulim Dam in Different Years In Different zones)			
(Capacity In ACRE FEET (MCM), Elevation in ft./m)			
YEAR	**El. 66.99 ft (20.42 m)**	**El.66.99 - 135 ft (20.42 – 41.15 m)**	**Overall**
1984	5837.13 (7.20)	184161.61 (227.16)	189998.74 (234.360)
2021	4154.09 (5.124)	165141.46 (203.70)	169295.55 (208.82)

Table-VIII A

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

ZONE	Dead storage	Live Storage	Overall
(Capacity in ACRE FEET (MCM), Elevation in ft./meter			
YEAR	**El. 66.99 ft (20.42 m)**	**El.66.99-135 ft (20.42-41.15 m)**	**Overall**
1984	-	-	-
2021	1683.04 (2.076)	19020.15 (23.46)	20703.19 (25.54)

Table-VIII B

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

ZONE	Dead storage	Live Storage	Overall
(Capacity in ACRE FEET (MCM), Elevation in ft./meter			
YEAR	**El. 66.99 ft (20.42 m)**	**El.66.99-135 ft (20.42-41.15 m)**	**Overall**
1984	-	-	-
2021	28.83	10.33	10.90

Table-VIII C

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

	(Capacity in ACRE FEET (MCM), Elevation in ft./meter		
ZONE	**Dead storage**	**Live Storage**	
YEAR	**El. 66.99 ft (20.42 m)**	**El.66.99-135 ft (20.42-41.15 m)**	**Overall**
1984	-	-	-
2021	0.78	0.28	0.29

Table-IX

Average Annual volume of Deposit

	VOLUME IN ACRE FEET (MCM)	
	1984	**2021**
1984	-	560 (0.7)

CONTOUR MAP (viii)

This section has been indicated contour map of Salaulim Reservoir

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

Contour Elevation (m)	Contour Elevation (ft)	Area		
		Sq. m	Hectare	Sq. Km
-0.1	-0.328	0.55	0.00	0.00
0.0	0.000	1.58	0.00	0.00
0.2	0.656	5.22	0.00	0.00
0.5	1.640	14.63	0.00	0.00
0.8	2.625	28.79	0.00	0.00
1.0	3.281	40.86	0.00	0.00
1.1	3.609	47.70	0.00	0.00
1.4	4.593	71.35	0.01	0.00
1.7	5.577	99.74	0.01	0.00
2.0	6.562	368.19	0.04	0.00
2.3	7.546	511.94	0.05	0.00
2.6	8.530	663.10	0.07	0.00
2.9	9.514	822.41	0.08	0.00
3.0	9.843	877.31	0.09	0.00
3.2	10.499	1007.90	0.10	0.00
3.5	11.483	1271.53	0.13	0.00
3.8	12.467	1594.49	0.16	0.00
4.0	13.123	1830.71	0.18	0.00
4.1	13.451	1963.90	0.20	0.00
4.4	14.436	2431.01	0.24	0.00
4.7	15.420	2878.99	0.29	0.00
5.0	16.404	3341.00	0.33	0.00
5.3	17.388	3891.19	0.39	0.00
5.6	18.373	4541.15	0.45	0.00
5.9	19.357	5295.66	0.53	0.01
6.0	19.685	5570.75	0.56	0.01
6.2	20.341	6144.21	0.61	0.01
6.5	21.325	7064.29	0.71	0.01
6.8	22.310	8306.39	0.83	0.01
7.0	22.966	9301.93	0.93	0.01
7.1	23.294	9849.93	0.98	0.01
7.4	24.278	11767.86	1.18	0.01
7.7	25.262	14402.04	1.44	0.01
8.0	26.247	18994.22	1.90	0.02
8.3	27.231	24217.49	2.42	0.02
8.6	28.215	29715.63	2.97	0.03
8.9	29.199	36415.47	3.64	0.04

Contour Elevation (m)	Contour Elevation (ft)	Area		
		Sq. m	Hectare	Sq. Km
9.0	29.528	38907.90	3.89	0.04
9.2	30.184	43959.90	4.40	0.04
9.5	31.168	51942.90	5.19	0.05
9.8	32.152	60249.22	6.02	0.06
10.0	32.808	66056.92	6.61	0.07
10.1	33.136	68880.76	6.89	0.07
10.4	34.121	77951.05	7.80	0.08
10.7	35.105	88596.72	8.86	0.09
11.0	36.089	100697.92	10.07	0.10
11.3	37.073	113465.91	11.35	0.11
11.6	38.058	126443.61	12.64	0.13
11.9	39.042	140124.70	14.01	0.14
12.0	39.370	145114.69	14.51	0.15
12.2	40.026	155626.88	15.56	0.16
12.5	41.010	172611.82	17.26	0.17
12.8	41.995	191043.79	19.10	0.19
13.0	42.651	204483.31	20.45	0.20
13.1	42.979	211310.78	21.13	0.21
13.4	43.963	233099.81	23.31	0.23
13.7	44.948	256142.06	25.61	0.26
14.0	45.932	278602.36	27.86	0.28
14.3	46.916	302295.01	30.23	0.30
14.6	47.900	329186.80	32.92	0.33
14.9	48.885	358488.08	35.85	0.36
15.0	49.213	368296.75	36.83	0.37
15.2	49.869	388478.03	38.85	0.39
15.5	50.853	420202.94	42.02	0.42
15.8	51.837	452995.40	45.30	0.45
16.0	52.493	477014.14	47.70	0.48
16.1	52.822	489259.38	48.93	0.49
16.4	53.806	526713.33	52.67	0.53
16.7	54.790	566252.44	56.63	0.57
17.0	55.774	609418.83	60.94	0.61
17.3	56.759	653898.02	65.39	0.65
17.6	57.743	700020.41	70.00	0.70
17.9	58.727	750106.39	75.01	0.75
18.0	59.055	767050.63	76.71	0.77
18.2	59.711	801444.80	80.14	0.80
18.5	60.696	854601.56	85.46	0.85
18.8	61.680	910342.34	91.03	0.91
19.0	62.336	948530.71	94.85	0.95

Contour Elevation (m)	Contour Elevation (ft)	Area		
		Sq. m	Hectare	Sq. Km
19.1	62.664	969212.55	96.92	0.97
19.4	63.648	1029365.06	102.94	1.03
19.7	64.633	1096678.45	109.67	1.10
20.0	65.617	1169869.83	116.99	1.17
20.3	66.601	1250705.22	125.07	1.25
20.4	66.995	1287025.08	128.70	1.29
20.6	67.585	1342511.69	134.25	1.34
20.9	68.570	1447161.67	144.72	1.45
21.0	68.898	1483224.34	148.32	1.48
21.2	69.554	1557228.45	155.72	1.56
21.5	70.538	1667428.28	166.74	1.67
21.8	71.522	1782711.14	178.27	1.78
22.0	72.178	1861824.09	186.18	1.86
22.1	72.507	1900252.20	190.03	1.90
22.4	73.491	2019149.76	201.91	2.02
22.7	74.475	2145170.41	214.52	2.15
23.0	75.459	2286409.40	228.64	2.29
23.3	76.444	2447725.24	244.77	2.45
23.6	77.428	2619816.80	261.98	2.62
23.9	78.412	2793102.13	279.31	2.79
24.0	78.740	2854104.91	285.41	2.85
24.2	79.396	2978352.61	297.84	2.98
24.5	80.381	3166430.22	316.64	3.17
24.8	81.365	3339051.94	333.91	3.34
25.0	82.021	3450153.68	345.02	3.45
25.1	82.349	3507279.48	350.73	3.51
25.4	83.333	3688950.23	368.90	3.69
25.7	84.318	3898249.93	389.82	3.90
26.0	85.302	4145378.18	414.54	4.15
26.3	86.286	4488504.96	448.85	4.49
26.6	87.270	4816030.14	481.60	4.82
26.9	88.255	5107397.35	510.74	5.11
27.0	88.583	5205715.71	520.57	5.21
27.2	89.239	5408508.02	540.85	5.41
27.5	90.223	5687173.65	568.72	5.69
27.8	91.207	5962488.67	596.25	5.96
28.0	91.864	6143346.95	614.33	6.14
28.1	92.192	6233428.95	623.34	6.23
28.4	93.176	6513386.44	651.34	6.51
28.7	94.160	6785692.85	678.57	6.79
29.0	95.144	7058325.22	705.83	7.06

Contour Elevation (m)	Contour Elevation (ft)	Area		
		Sq. m	Hectare	Sq. Km
29.3	96.129	7344940.09	734.49	7.34
29.6	97.113	7625418.11	762.54	7.63
29.9	98.097	7915255.61	791.53	7.92
30.0	98.425	8011182.69	801.12	8.01
30.2	99.081	8199335.72	819.93	8.20
30.5	100.066	8486287.04	848.63	8.49
30.8	101.050	8776452.15	877.65	8.78
31.0	101.706	8971455.80	897.15	8.97
31.1	102.034	9071723.30	907.17	9.07
31.4	103.018	9381025.20	938.10	9.38
31.7	104.003	9692083.48	969.21	9.69
32.0	104.987	10010724.88	1001.07	10.01
32.3	105.971	10334686.40	1033.47	10.33
32.6	106.955	10674079.59	1067.41	10.67
32.9	107.940	11022121.26	1102.21	11.02
33.0	108.268	11139136.28	1113.91	11.14
33.2	108.924	11381595.43	1138.16	11.38
33.5	109.908	11761242.23	1176.12	11.76
33.8	110.892	12157625.14	1215.76	12.16
34.0	111.549	12417472.53	1241.75	12.42
34.1	111.877	12547927.66	1254.79	12.55
34.4	112.861	12935922.02	1293.59	12.94
34.7	113.845	13307453.80	1330.75	13.31
35.0	114.829	13689719.88	1368.97	13.69
35.3	115.814	14082569.61	1408.26	14.08
35.6	116.798	14477051.79	1447.71	14.48
35.9	117.782	14863904.63	1486.39	14.86
36.0	118.110	14991331.66	1499.13	14.99
36.2	118.766	15241391.05	1524.14	15.24
36.5	119.751	15625982.70	1562.60	15.63
36.8	120.735	16024677.16	1602.47	16.02
37.0	121.391	16296590.15	1629.66	16.30
37.1	121.719	16437590.96	1643.76	16.44
37.4	122.703	16881007.59	1688.10	16.88
37.7	123.688	17364251.71	1736.43	17.36
38.0	124.672	17922056.44	1792.21	17.92
38.3	125.656	18491264.83	1849.13	18.49
38.6	126.640	18998487.90	1899.85	19.00
38.9	127.625	19498528.56	1949.85	19.50
39.0	127.953	19665892.62	1966.59	19.67
39.2	128.609	20012634.03	2001.26	20.01

Contour Elevation (m)	Contour Elevation (ft)	Area		
		Sq. m	Hectare	Sq. Km
39.5	129.593	20482162.05	2048.22	20.48
39.8	130.577	20946659.25	2094.67	20.95
40.0	131.234	21267260.35	2126.73	21.27
40.1	131.562	21536010.14	2153.60	21.54
40.4	132.546	21924561.88	2192.46	21.92
40.7	133.530	22291308.88	2229.13	22.29
41.0	134.514	22663583.92	2266.36	22.66
41.15	135.007	22856028.90	2285.60	22.86
41.3	135.499	23106622.65	2310.66	23.11
41.6	136.483	23530990.07	2353.10	23.53
41.9	137.467	23911628.27	2391.16	23.91
42.0	137.795	24036854.93	2403.69	24.04
42.2	138.451	24287258.85	2428.73	24.29
42.5	139.436	24668607.78	2466.86	24.67
42.8	140.420	25104852.55	2510.49	25.10
43.0	141.076	25367039.03	2536.70	25.37
43.1	141.404	25499175.41	2549.92	25.50
43.4	142.388	25900661.10	2590.07	25.90
43.7	143.373	26445023.16	2644.50	26.45
44.0	144.357	26888980.32	2688.90	26.89
44.3	145.341	27332784.94	2733.28	27.33
44.6	146.325	27835238.14	2783.52	27.84
44.9	147.310	28286596.05	2828.66	28.29
45.0	147.638	28436829.77	2843.68	28.44
45.2	148.294	28733096.56	2873.31	28.73
45.5	149.278	29180595.34	2918.06	29.18

Table 8-Elevation wise Area of Salaulim Dam

16.1 Contour map of Salaulim Dam:-
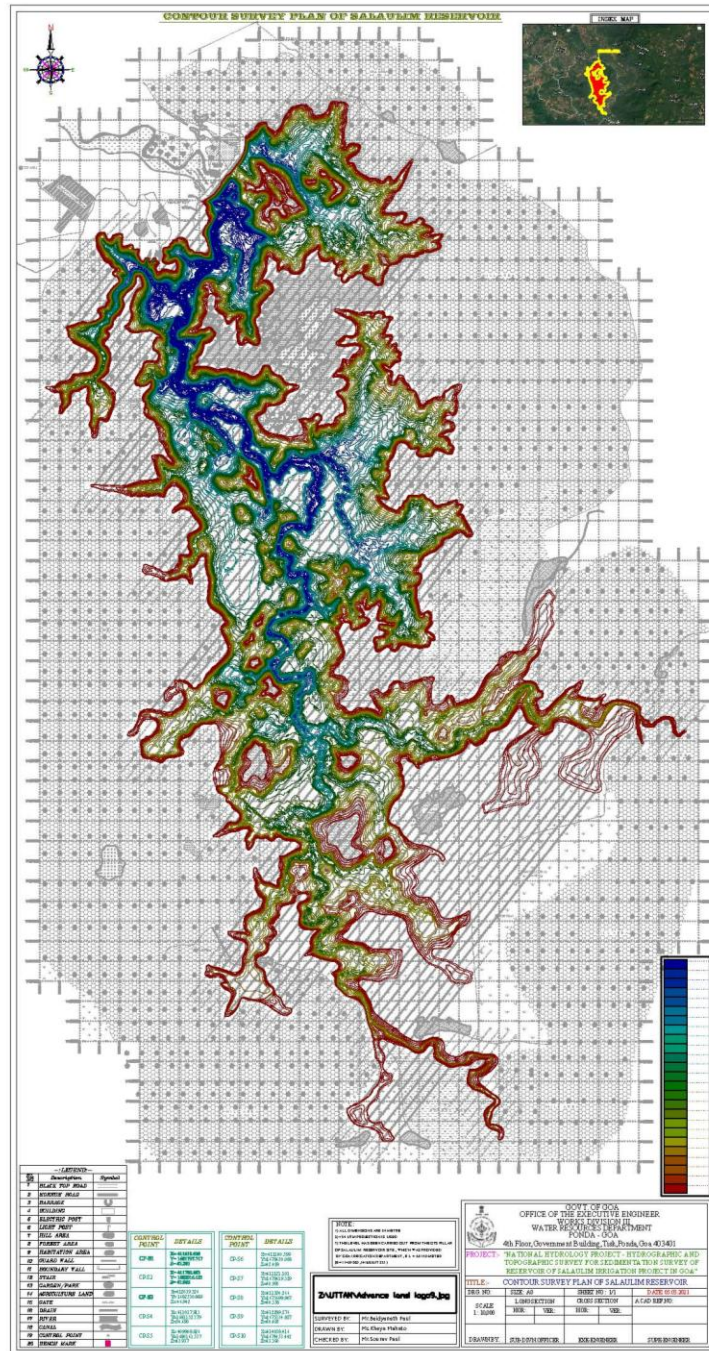
Figure 16-Contour plan of Salaulim Dam

TRAP EFFICIENCY (ix)

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

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

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

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

Therefore, trap Efficiency:-

Total Sediment deposited in the Dam

Total Sediment Flowing in the River

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

Trap efficiency of a reservoir, over a period is the ratio of the total deposited sediment to the total sediment inflow. Brune (1953) developed an empirical relationship for estimating long-term trap efficiency in normally impounded reservoirs based on the correlation between the capacity to inflow ratio (C: I) and trap efficiency observed in Tennessee Valley Authority reservoirs in the south-eastern United States. Brune analysed data from 44 reservoirs with catchment areas varying from small to very large and presented a median curve together with lower and upper envelope curves which shows in Figure 0-1.
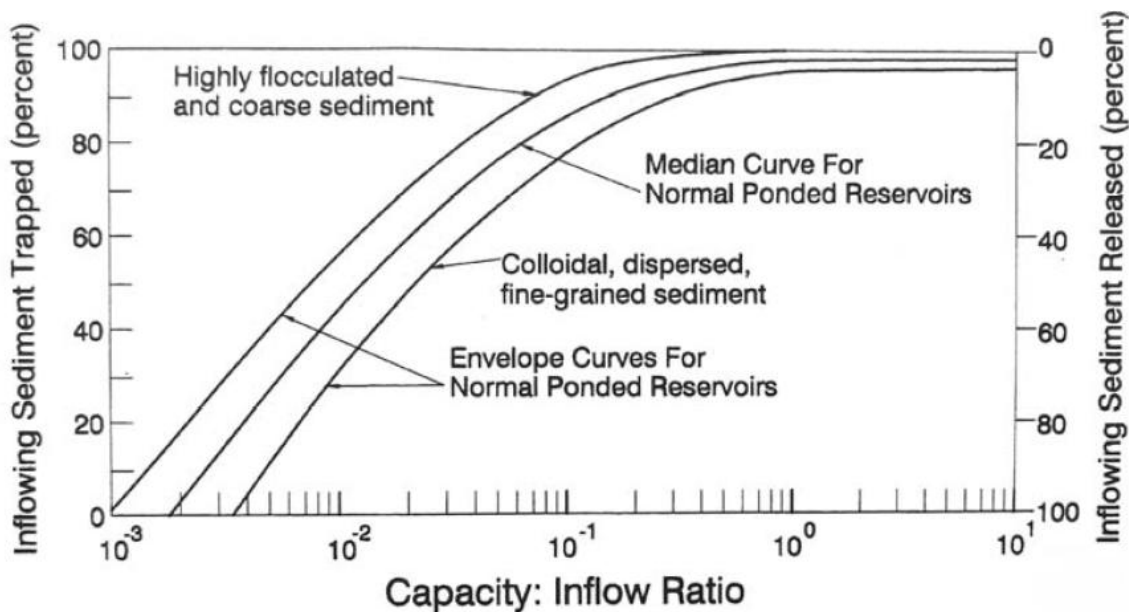
Figure 0-1   Brune curve for estimating sediment trapping or release efficiency inconventional impounding reservoirs (adapted from Brune. 1953)

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

Capacity = Capacity of Reservoir at FRL

Inflow = Average annual inflow in volumetric unit

For Salaulim Dam C = 208.823 MCM based on 2021 survey

I = 231.29 MCM

C/I = 0.9

Trap efficiency corresponding to above ratio C/I as read from median curve of Figure 0-1 for normally ponded reservoir is 97.2%.

CHARTS/DRAWINGS (x)

18.0 Charts/Drawing:-

18.1 Grid Plan of Salaulim Dam:-
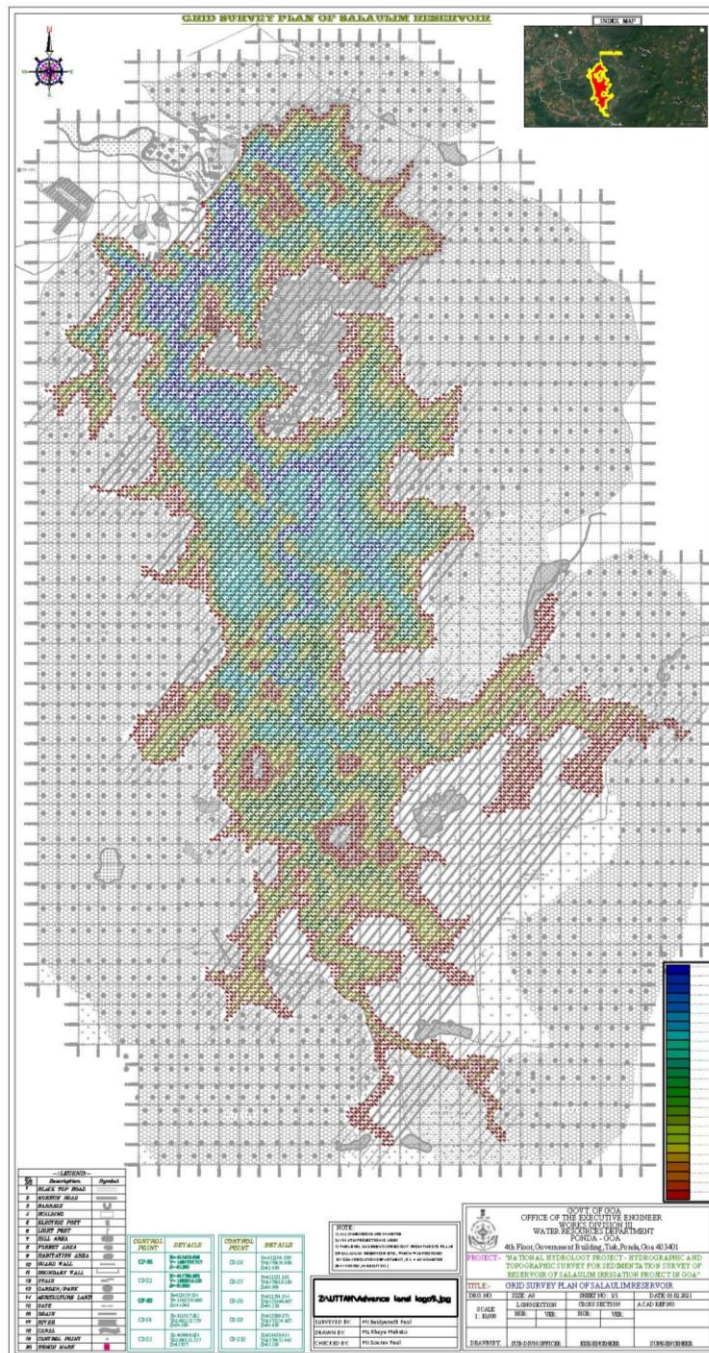
Figure 2-Grid Plan of Salaulim Dam

18.2 Topographical Plan of Salaulim Dam:-
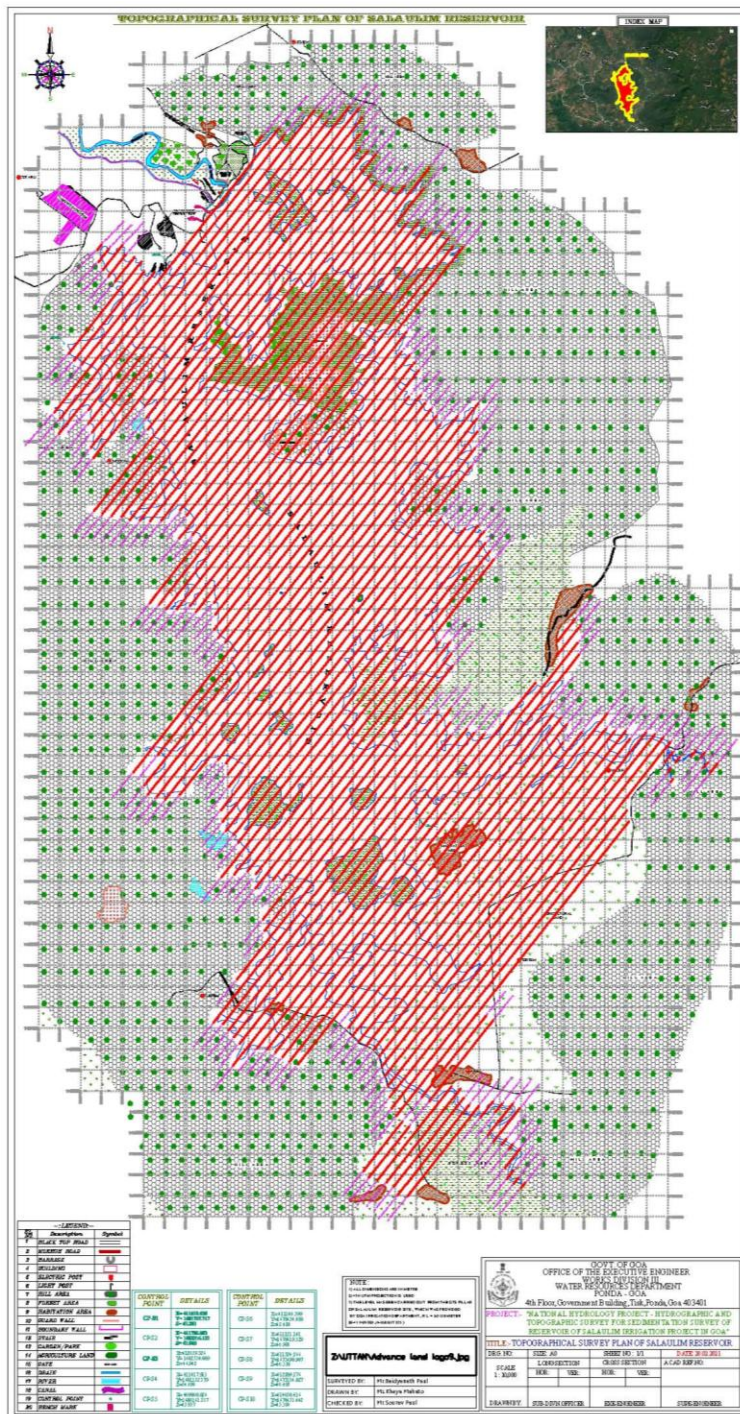
Figure 3-Topographical plan of Salaulim Dam

CONCLUSIONS/RECOMMENDATIONS (XI)

19.0 Conclusion and Recommendation:-

The conclusion drawn from this study is given below:

- Volume of sediment deposition is determined from 1984 and 2021 survey. It is observed that loss of total storage i.e., deposition/accumulation of sediment in 37 years is 25.537 MCM upto FRL. Deposition of sediment per year is 0.69 MCM/year. Capacity at MWL 45.5 m is not available in 1984. At 43 m capacity is 308 MCM and 253 MCM in 1984 and 2021, respectively. Total deposition upto 43 m is 55 MCM. But upto FRL i.e., 41.15 m is 25.537 MCM. Between 41.15 m and 43 m deposition is (55-25.537) = 29.463 MCM. This value is too high and unrealistic as water is normally maintained at FRL and reaches 43 m only when very high discharge enters. This may happen due sudden landslide.

- Total deposition of sediment per year is 0.69 MCM/year upto FRL (41.15 m).Catchment area = 209.04 km^2 Sediment yield = 3.3 mm/km^2/yr. Total deposition of sediment per year is 1.48 MCM/year considering sediment deposition upto 43 m. catchment area = 209.04 km^2, Sediment yield = 7.08 mm/km^2/yr

- Trap efficiency for Salaulim Dam corresponding to capacity: inflow ratio (C/I) of 0.9 considering normally ponded reservoir is 97.2%.

- According to IS 12182 – 1987 1987"Guidelines for Determination of Effects of Sedimentation in Planning and Performance of Reservoirs" 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. For Salaulim Dam upto FRL capacity is 208.823 MCM, Sediment deposition per year = 0.69 MCM upto FRL, average annual volume of sediment deposition with the gross capacity of the reservoir = 0.69/208.823 = 0.33% which is between 0.1% and 0.5%. The sediment problem is significant. For Salaulim Dam taking sediment deposition upto 43 m capacity is 253 MCM. Sediment deposition per year = 1.48 MCM upto 43 m. Average annual volume of sediment deposition with the gross capacity of the reservoir = 1.48/253 = 0.58% which is greater than 0.5%. The sediment problem is serious.

- It is observed that dead storage will be depleted within 50 years from 2021 and new zero elevation will be above dead storage level.

- 16.5% of live storage will be depleted within 50 years from 2021.

- 23% of live storage will be depleted within 70 years from 2021.

- 33% of live storage will be depleted within 100 years from 2021.

- New zero elevation after 50 year and 100 year will be 20.6 m and 25.4m respectively.

Recommendation:-

Following recommendations are given:

- Cause of high deposition of sediment in Salulim dam between FRL and MWL may be investigated further. In Salulim catchment lots of mining activity occurs which may cause landslide and such deposition of sediment. Sediment samples may further to be analyzed from this zone to find out type of sediment and cause of such deposition to avoid flooding problem in future due to reduction of flood storage.

- The loss of storage will have an impact on storage of water. Simulation studies need to be done to assess water demands with desired reliability will be fulfilled in future.

- Suspended sediment data need to be collected each year for monsoon period to understand the sediment inflow coming each year during monsoon.

- As a common practice, sediment management can be done either by flushing or sluicing. Flushing can be done if enough water is available. Otherwise sluicing with maintaining low water level during peak flood can be option. There is no sluice available, and flushing is also a problem for this dam.

- In such cases it is recommended to find the source of sediment from the catchment and a detailed study need to be done for catchment area treatment plan. Salulim reservoirs catchment is highly affected with mining activities. In such cases it may not be viable to prepare an effective catchment treatment plan and implementation of the same.

- Dredging could be another option for sediment management. It may be an effective solution of sediment management provided it is cost effective and if an eco-friendly deposition site is identified in the vicinity of the reservoirs. It is recommended to do a separate study to find out efficacy of dredging considering cost and eco-friendly deposition site.

- **Limitation on sediment study:-**

Sediments are deposited in reservoirs at all elevations, causing the stage-capacity curve to shift. Empirical methods have been developed to distribute sediment deposits within a reservoir as a function of depth, thereby projecting the shift in the stage-storage curve. These methods are much quicker and easier to use than mathematical modelingand also require less data. When sediment survey data are available for an existing reservoir, the observed deposition pattern can be used to select the proper empirical relationship to compute the future shift in the stage-area and stage-capacity relationships. As a limitation, empirical methods do not identify the specific locations in a reservoir which will be affected by sediment; they predict only the change in the stage-area and stage-capacity curves. A significant shift in the operating regime, such as implementation of sediment management, will affect the deposition pattern. Empirical methods cannot be user to simulate these effects, and the evaluation of management alternatives requires numerical modeling.

20.0 Personnel:-

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

- # Survey:-
  1. Shri Baidyanath Pal, Surveyor
  2. Shri, Nayan Manna, Assistant Surveyor
  3. Shri Dipankar Mal, Assistant Surveyor
  4. Suvra Das, Assistant Surveyor

- # Official Incharge of Salaulim (Dam) Irrigation Project:-

  1. **Jason D. Menezes, Assistant Engineer**
  2. **Swapnil D. Divkar, Junior Engineer**

20.1 Guidance/Recommendation and consultation of the Report:-

Name- Shri Bimalendu Ghosh

Designation- Senior Survey Consultant

The Institution of Surveyors (Delhi)

Name-Shri Apurban Mukherjee

Designation- Specialisation in Water Resources,

IIT, Guwahati

20.2 Certificate of Bimalendu Ghosh:-
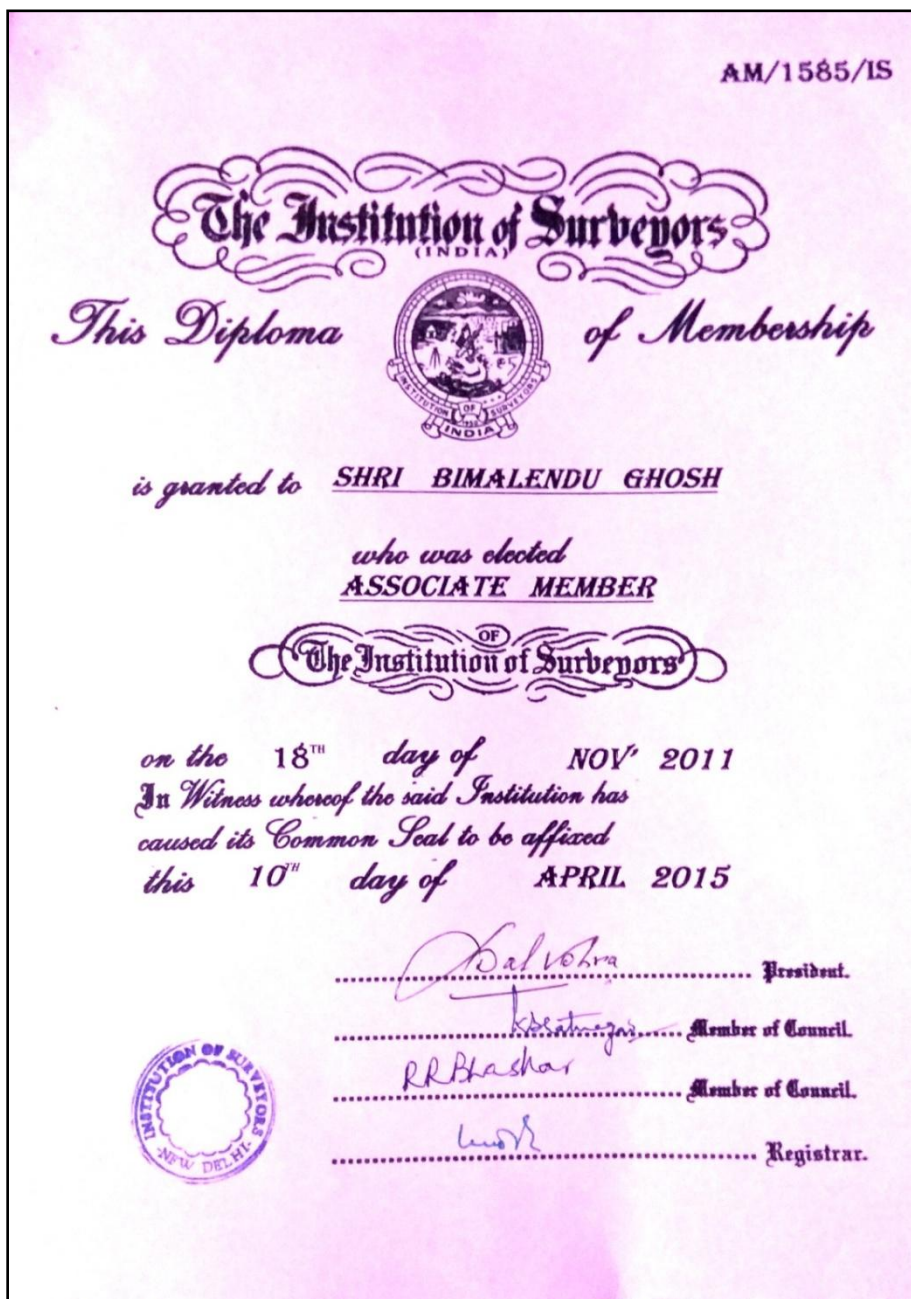
20.3 Certificate of Apurban Mukherjee:-

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी

विद्या परिषद की अनुशंसा पर

सिविल अभियांत्रिकी में

प्रौद्योगिकी निष्णात की उपाधि

(विशेषज्ञता: वॉटर रिसोर्सेज़ः युटिलाइजेशन ऐन्ड एनवायरॉन्मेंटल मैनेजमेंट)

अपरुबन मुखर्जी

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

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

INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

upon the recommendation of the Senate hereby confers the degree of

Master of Technology

in

Civil Engineering

(Specialisation: Water Resources : Utilisation and Environmental Management)

on

Apruban Mukherjee

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

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

निदेशक एवं
अध्यक्ष, विद्या परिषद
Director and
Chairman, Senate

कुलसचिव
Registrar

अध्यक्ष,
शासी मंडल
Chairman,
Board of Governors

SITE IMAGES

21.0 Site Images:-
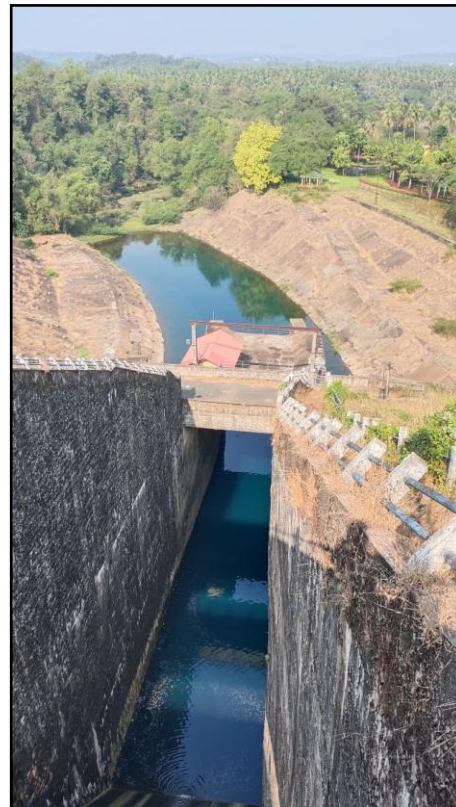
ANNEXURE-I

(MODEL STUDY WITH EXECUTIVE SUMMARY)

Executive Summary

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

For this study following data is required.

- Elevation-area-capacity survey at present year and original elevation-area-capacity survey to understand deposition of sediment volume.

- Annual inflow for 30 years or more

In this study sedimentation survey of 1984 i.e., original elevation-area-capacity and elevation-area-capacity survey in 2021 are received. No inflow data are received. Seven years of water demand data are received.

A comparison of reservoir capacity between year 1984 and 2021 are presented in Figure 0-1.As per the sedimentation survey of 1984, original allocated capacity i.e., gross storage is 234.36 MCM up to elevation of 41.15 m i.e., FRL. Survey done in 2021 shows capacity is 208.823 MCM at elevation of 41.15 m. Salient features of reservoir related to storage in 1984 and 2021 is given below. It is observed that loss of total storage i.e., deposition/accumulation of sediment in 37 years is 25.537 MCM upto FRL. Deposition of sediment per year is 0.69 MCM/year. Capacity at MWL 45.5 m is not available in 1984. At 43 m capacity is 308 MCM and 253 MCM in 1984 and 2021, respectively. Total deposition upto 43 m is 55 MCM. But upto FRL i.e., 41.15 m is 25.537 MCM. Between 41.15 m and 43 m deposition is (55-25.537) = 29.463 MCM. This value is too high and unrealistic as water is normally maintained at FRL and reaches 43 m only when remarkably high discharge enters. This may happen due sudden landslide. Therefore, trial and error process are done to make sure deposition rate at FRL is 0.69 MCM/year. It is observed that reduction in Capacity 7.2 MCM to 5.124 MCM in dead storage.

Figure 0-1   Comparison of reservoir capacity between year 1984 and 2021

	FRL	41.15 m	Capacity at DSL in 2021	5.124 MCM
Dead storage level		20.4 m	Live storage in 1984	227.16 MCM
Capacity at FRL in 1984		234.36 MCM	Dead storage in 1984	7.2 MCM
Capacity at DSL in 1984		7.2 MCM	Live storage in 2021	203.70 MCM
Capacity at FRL in 2021		208.823 MCM	Dead storage in 2021	5.124 MCM

Catchment area of Salaulim Dam is 209.04 km2. Annual sediment deposition is 0.69 MCM/year upto FRL. Sediment yield becomes 3.3 mm/km2/yr.

Total deposition of sediment per year is 1.48 MCM/year considering sediment deposition upto 43 m. Sediment yield becomes 7.08 mm/km2/yr.

According to IS 12182 – 1987 1987"Guidelines for Determination of Effects of Sedimentation in Planning and Performance of Reservoirs" 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 ran be neglected for studies of reservoir performance. For cases falling between these two limits, the sedimentation problem is considered significant and requires further studies.

For Salaulim Dam upto FRL capacity is 208.823 MCM

Sediment deposition per year = 0.69 MCM upto FRL

Average annual volume of sediment deposition with the gross capacity of the reservoir = 0.69/208.823 = 0.33% which is between 0.1% and 0.5%. **The sediment problem is significant.**

For Salaulim Dam upto 43 m capacity is 253.469 MCM

Sediment deposition per year = 1.48 MCM upto FRL

Average annual volume of sediment deposition with the gross capacity of the reservoir = 1.48/253.469 = 0.58% which is greater than 0.5%. **The sediment problem is serious**.

Based on available data from client mean annual inflow is 231.29 MCM. Trap efficiency for Salaulim Dam corresponding C/I of 0.9 considering normally ponded reservoir is 97.2%.Brune curve is used to estimate trap efficiency. Area-reduction method is used to predict distribution of sediment in Salaulim Reservoir. Following steps are used:

- Sediment inflow is determined from 1984 and 2021 survey. Deposition of sediment volume is 25.537 mcm upto FRL. Deposition of sediment volume per year is 0.69 MCM upto FRL.

- Design curve is selected based on the original depth-capacity (1984). This relationship on log-log paper is plotted and the slope m of the fitted line, which is the reciprocal of the slope of the depth versus capacity plot. Design curve for tendency of sediment is Floodplain-foothill reservoir i.e., type II.

- Computation of new zero-capacity elevation at dam using Moody's method. Area corresponding to zero-capacity elevation is computed from original elevation area-capacity curve.

- Distribution of the specified volume of trapped sediment within the reservoir according to the type II reservoir.

Using aforesaid methodology Elevation-Area-Capacity curve is estimated for every 10-year upto 100 year considering 2021 as base year. Figure below shows Elevation-capacity for 10, 30, 50, 70 and 100 year for Salaulim Reservoir. New zero elevation at every 10 year is given in Table 0-1.

Figure 0-2   Elevation-capacity curve for different year for Salaulim Reservoir

Table 0-1   New zero elevation at every 10 year

Year	New Zero Elevation (m)	Year	New Zero Elevation (m)
10 yr	12.5	60 yr	22
20 yr	16	70 yr	22.4
30 yr	18	80 yr	23.6
40 yr	19.4	90 yr	24.5
50 yr	20.6	100 yr	25.4

It is observed from the study that capacity of reservoir at FRL is reduced from 208.49 MCM to 139.80 MCM in 100 years. Total reservoir capacity at every 10 year is depicted in Figure 0-3.

Figure 0-3   Comparison of reduced reservoir capacity at FRL (10-year interval)

The conclusion drawn from this study is given below:

- Volume of sediment deposition is determined from 1984 and 2021 survey. It is observed that loss of total storage i.e., deposition/accumulation of sediment in 37 years is 25.537 MCM upto FRL. Deposition of sediment per year is 0.69 MCM/year. Capacity at MWL 45.5 m is not available in 1984. At 43 m capacity is 308 MCM and 253 MCM in 1984 and 2021, respectively. Total deposition upto 43 m is 55 MCM. But upto FRL i.e., 41.15 m is 25.537 MCM. Between 41.15 m and 43 m deposition is (55-25.537) = 29.463 MCM. This value is too high and unrealistic as water is normally maintained at FRL and reaches 43 m only when very high discharge enters. This may happen due sudden landslide.

- Total deposition of sediment per year is 0.69 MCM/year upto FRL (41.15 m).Catchment area = 209.04 km^{2}Sediment yield = 3.3 mm/km^2/yr. Total deposition of sediment per year is 1.48 MCM/year considering sediment deposition upto 43 m. catchment area = 209.04 km^2, Sediment yield = 7.08 mm/km^2/yr

- Trap efficiency for Salaulim Dam corresponding to capacity: inflow ratio (C/I) of 0.9 considering normally ponded reservoir is 97.2%.

- According to IS 12182 – 1987 1987"Guidelines for Determination of Effects of Sedimentation in Planning and Performance of Reservoirs" 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. For Salaulim Dam upto FRL capacity is 208.823 MCM, Sediment deposition per year = 0.69 MCM upto FRL, average annual

volume of sediment deposition with the gross capacity of the reservoir = 0.69/208.823 = 0.33% which is between 0.1% and 0.5%. The sediment problem is significant. For Salaulim Dam taking sediment deposition upto 43 m capacity is 253 MCM. Sediment deposition per year = 1.48 MCM upto 43 m. Average annual volume of sediment deposition with the gross capacity of the reservoir = 1.48/253 = 0.58% which is greater than 0.5%. The sediment problem is serious.

- It is observed that dead storage will be depleted within 50 years from 2021 and new zero elevation will be above dead storage level.

- 16.5% of live storage will be depleted within 50 years from 2021.

- 23% of live storage will be depleted within 70 years from 2021.

- 33% of live storage will be depleted within 100 years from 2021.

- New zero elevation after 50 year and 100 year will be 20.6 m and 25.4 m respectively.

Following recommendations are given:

- Cause of high deposition of sediment in Salulim dam between FRL and MWL may be investigated further. In Salulim catchment lots of mining activity occurs which may cause landslide and such deposition of sediment. Sediment samples may further to be analyzed from this zone to find out type of sediment and cause of such deposition to avoid flooding problem in future due to reduction of flood storage.

- The loss of storage will have an impact on storage of water. Simulation studies need to be done to assess water demands with desired reliability will be fulfilled in future.

- Suspended sediment data need to be collected each year for monsoon period to understand the sediment inflow coming each year during monsoon.

- As a common practice, sediment management can be done either by flushing or sluicing. Flushing can be done if enough water is available. Otherwise sluicing with maintaining low water level during peak flood can be option. There is no sluice available, and flushing is also a problem for this dam.

- In such cases it is recommended to find the source of sediment from the catchment and a detailed study need to be done for catchment area treatment plan.Salulim reservoirs catchment is highly affected with mining activities. In such cases it may not be viable to prepare an effective catchment treatment plan and implementation of the same.

- Dredging could be another option for sediment management. It may be an effective solution of sediment management provided it is cost effective and if an eco-friendly deposition site is identified in the vicinity of the reservoirs. It is recommended to do a separate study to find out efficacy of dredging considering cost and eco-friendly deposition site.

5. Introduction:-

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

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

6. Data Collection:-

For this study following data is required.

- Elevation-area-capacity survey at present year and original elevation-area-capacity survey to understand deposition of sediment volume.

- Annual inflow for 30 years or more

In this study sedimentation survey of 1984 i.e., original elevation-area-capacity and elevation-area-capacity survey in 2021 are received. No inflow data are received. Seven years of water demand data are received. These data are used to estimate inflow. Seven years of data may not be representative and may give over or underestimate of average annual inflow. It would have an impact on capacity to inflow ratio which may lead to impact on trap efficiency.

7. Capacity of reservoir and annual sediment deposition:-

A comparison of reservoir capacity between year 1984 and 2021 are presented in Figure 0-4. As per the sedimentation survey of 1984, original allocated capacity i.e., gross storage is234.36 MCM up to elevation of 41.15 m i.e., FRL. Survey done in 2021 shows capacity is 208.823 MCM at elevation of 41.15 m. Salient features of reservoir related to storage in 1984 and 2021 is given in Table 0-2. It is observed that loss of total storage i.e., deposition/accumulation of sediment in 37 years is 25.537 MCM upto FRL. Deposition of sediment per year is 0.69 MCM/year. Capacity at MWL 45.5 m is not available in 1984. At 43 m capacity is 308 MCM and 253 MCM in 1984 and 2021, respectively. Total deposition upto 43 m is 55 MCM. But upto FRL i.e., 41.15 m is 25.537 MCM. Between 41.15 m and 43 m deposition is (55-25.537) = 29.463 MCM. This value is too high and unrealistic as water is normally maintained at FRL and reaches 43 m only when very high discharge enters. This may happen due sudden landslide. Therefore, trial and error process are done to make sure deposition rate at FRL is 0.69 MCM/year. It is observed that reduction in Capacity 7.2 MCM to 5.124 MCM in dead storage.

Figure 0-4   Comparison of reservoir capacity between year 1984 and 2021

Table 0-2   Salient features of Salaulim reservoir related to storage in 1984 and 2021

FRL	41.15 m
Dead storage level	20.4 m
Capacity at FRL in 1984	234.36 MCM
Capacity at DSL in 1984	7.2 MCM
Capacity at FRL in 2021	208.823 MCM
Capacity at DSL in 2021	5.124 MCM
Live storage in 1984	227.16 MCM
Dead storage in 1984	7.2 MCM
Live storage in 2021	203.70 MCM
Dead storage in 2021	5.124 MCM

Catchment area of Salaulim Dam is 209.04 km^2. Annual sediment deposition is 0.69 MCM/year upto FRL. Sediment yield becomes 3.3 mm/km^2/yr.

Total deposition of sediment per year is 1.48 MCM/year considering sediment deposition upto 43 m. Sediment yield becomes 7.08 mm/km^2/yr.

8. Seriousness of Problem:-

According to IS 12182 – 1987 1987"Guidelines for Determination of Effects of Sedimentation in Planning and Performance of Reservoirs" 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 ran be neglected for studies of reservoir performance. For cases falling between these two limits, the sedimentation problem is considered significant and requires further studies.

For Salaulim Dam upto FRL capacity is 208.823 MCM

Sediment deposition per year = 0.69 MCM upto FRL

Average annual volume of sediment deposition with the gross capacity of the reservoir = 0.69/208.823 = 0.33% which is between 0.1% and 0.5%. **The sediment problem is significant.**

For Salaulim Dam upto 43 m capacity is 253.469 MCM

Sediment deposition per year = 1.48 MCM upto FRL

Average annual volume of sediment deposition with the gross capacity of the reservoir = 1.48/253.469 = 0.58% which is greater than 0.5%. **The sediment problem is serious**.

9. Area-reduction method:-

The Elevation-Area-Capacity curve and is produced for another 100 years at 10 years interval using Area-reduction method. Year 2021 is considered as base year. Elevation-Area-Capacity surveyed in 2021 is used as a base data. Elevation-Area-Capacity for 2021 is shown in Table 0-3

Table 0-3   Elevation-Area-Capacity in 2021

Elevation m	Area ha	Capacity MCM	Elevation m	Area ha	Capacity MCM	Elevation m	Area ha	Capacity MCM
45.5	2918.1	321.64	30	801.1183	43.67	14.6	32.91868	0.911
45	2843.7	307.24	29.6	762.5418	40.54	14	27.86024	0.729
44.6	2783.5	295.98	29	705.8325	36.14	13.4	23.30998	0.575
44	2688.9	279.57	28.4	651.3386	32.07	13	20.44833	0.488
43.4	2590.1	263.72	28	614.3347	29.54	12.5	17.26118	0.394
43	2536.7	253.47	27.5	568.7174	26.58	12	14.51147	0.314
42.5	2466.9	240.96	27	520.5716	23.85	11.6	12.64436	0.260004
42	2403.7	228.78	26.6	481.603	21.85	11	10.06979	0.192
41.6	2353.1	219.27	26	414.5378	19.16	10.4	7.795105	0.139
41.15	**2285.6**	**208.82**	25.4	368.895	16.81	10	6.605692	0.110
40.4	2192.5	192.03	25	345.0154	15.38	9.5	5.19429	0.080
40	2126.7	183.37	24.5	316.643	13.73	9	3.89079	0.058
39.5	2048.2	172.94	24	285.4105	12.23	8.6	2.971563	0.044
39	1966.6	162.90	23.6	261.9817	11.13	8	1.899422	0.029
38.6	1899.8	155.16	23	228.6409	9.66	7.4	1.176786	0.020
38	1792.2	144.08	22.4	201.915	8.37	7	0.930193	0.016
37.4	1688.1	133.65	22	186.1824	7.60	6.5	0.706429	0.012
37	1629.7	127.01	21.5	166.7428	6.71	6	0.557075	0.009001
36.5	1562.6	119.03	21	148.3224	5.93	5.6	0.454115	0.0070

Elevation m	Area ha	Capacity MCM	Elevation m	Area ha	Capacity MCM	Elevation m	Area ha	Capacity MCM
36	1499.1	111.38	20.6	134.2512	5.36	5	0.3341	0.0046
35.6	1447.7	105.49	20	116.987	4.61	4.4	0.243101	0.0029
35	1369	97.04	19.4	102.9365	3.95	4	0.183071	0.002054
34.4	1293.6	89.05	19	94.85307	3.55	3.5	0.127153	0.001282
34	1241.7	83.98	18.5	85.46016	3.10	3	0.087731	0.000751
33.5	1176.1	77.93	18	76.70506	2.70	2.6	0.06631	0.000444
33	1113.9	72.21	17.6	70.00204	2.40	2	0.036819	0.000135
32.6	1067.4	67.85	17	60.94188	2.01	1.4	0.007135	0.000040
32	1001.1	61.65	16.4	52.67133	1.67	1	0.004086	0.000017
31.4	938.1	55.83	16	47.70141	1.47	0.5	0.001463	0.000004
31	897.15	52.16	15.5	42.02029	1.25	0	0	0.000000
30.5	848.63	47.80	15	36.82968	1.05			

The steps and results are described in this section.

Determine sediment inflow: Volume of sediment deposition is determined from 1984 and 2021survey. Deposition of sediment volume is25.537 mcm upto FRL. Deposition of sediment volume per year is 0.69 MCM upto FRL.

Selection of design curve: Strand and Pemberton state that the reservoir does not change type with continued sediment deposition unless reservoir operation changes. Thus, the stage-capacity plot should be based on the original reservoir bathymetry, not the bathymetry following sediment accumulation. The original depth-capacity (1984) relationship on log-log paper is plotted and the slope m of the fitted line, which is the reciprocal of the slope of the depth versus capacity plot (Figure 0-5) is calculated. When the slope m does not plot as a straight line, shape type corresponding to the predominate overall slope, or the slope in the area of the reservoir where most of the sediment will deposit, are used. It is noticed that slope m is following straight line above depth 0.2 m i.e., between 17 m and 43 m and it is predominant. Therefore, slope in this area is used.

m = 3.25 type = II

Figure 0-5　　　Reservoir depth-capacity relationship forsalaulim Reservoir

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

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

The type curves in Figure 0-5 reflect the tendency for sediment is Floodplain-foothill reservoir i.e., type II.

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

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

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

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

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

Figure 0-6 shows the plotting off f (p) against relative reservoir depth, p, for the four types of reservoirs and value is given in Table 0-4.

Figure 0-6   Type curves for determining the new zero depth at the dam.

Table 0-4   Values of the Functionf(p) for the Four Types of Reservoirs

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

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

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

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

The relative depth p is computed as

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

Where h_{min} = original bottom elevation

The resulting F and p values on the type curves are presented in Figure 0-7. The intersection of the plotted F values with the type of curve selected for the reservoir defines the p_0 value for the new zero-capacity elevation at the dam. Intersection occurs at p_0 = 0.283, 0.46, 0.558 for 10 yr, 50 yr and 100 yr respectively.

Figure 0-7   Type curves for determining the new zero depth at the dam based on thedimensionless Ffunction.

The new zero-capacity elevation is given by $h_0 = (p_0H + h_{min}) = 0.283 (45.5-0) + 45.5 = 12.876$ m for 10 yr. Area corresponding to zero-capacity elevation is computed from original elevation area-capacity curve.

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

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

The relative sediment area 'a' at the new zero elevation is computed for 10 yr, a = 1.0567 and the area correction factor is A0/a = 18.519.

Figure 0-8   Sediment distribution – Area design curves (Based on reservoir storage curve)

Using aforesaid methodology Elevation-Area-Capacity curve is estimated for every 10-year upto 100 year considering 2021 as base year. Figure 0-9and Table 0-5 shows Elevation-capacity for 10, 30, 50, 70 and 100 year. A sample calculation is given in Appendix A for 30 year.
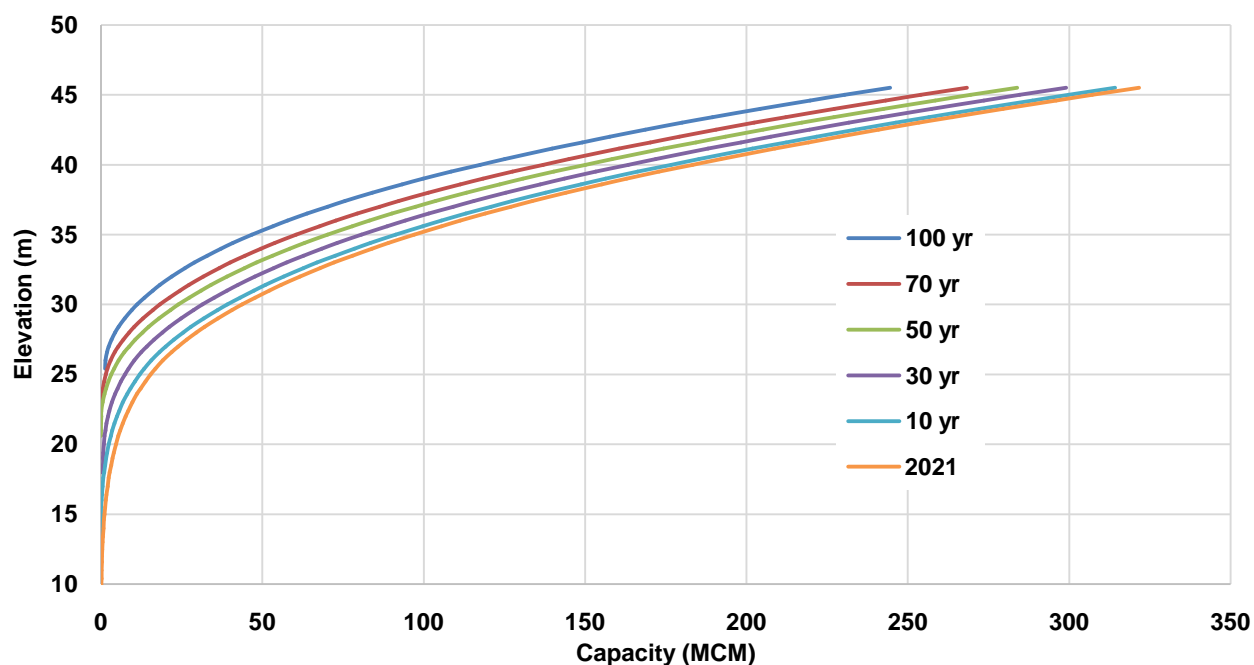
Figure 0-9   Elevation-capacity curve for different year for Salaulim Reservoir

Table 0-5   Elevation-capacity for different year for Salaulim Reservoir

Elevation (m)	Capacity (MCM)					
	2021	10yr	30yr	50yr	70yr	100yr
45.50	321.641	314.222	299.067	283.854	268.277	244.557
45.00	307.237	299.836	284.728	269.564	254.049	230.434
44.60	295.982	288.615	273.591	258.516	243.113	219.689
44.00	279.574	272.267	257.403	242.494	227.299	204.230
43.40	263.722	256.487	241.810	227.096	212.147	189.495
43.00	253.469	246.286	231.746	217.176	202.408	180.062
42.50	240.956	233.843	219.487	205.109	190.581	168.646
42.00	228.780	221.742	207.582	193.407	179.136	157.637
41.60	219.266	212.291	198.295	184.291	170.236	149.102
41.15	208.823	201.921	188.117	174.314	160.510	139.804
40.40	192.033	185.260	171.791	158.337	144.973	125.014

Elevation (m)	Capacity (MCM)					
	2021	10yr	30yr	50yr	70yr	100yr
40.00	183.374	176.672	163.389	150.128	137.008	117.465
39.50	172.939	166.327	153.283	140.272	127.465	108.454
39.00	162.896	156.379	143.581	130.825	118.340	99.876
38.60	155.164	148.723	136.125	123.579	111.357	93.340
38.00	144.078	137.755	125.465	113.239	101.421	84.090
37.40	133.648	127.446	115.471	103.574	92.169	75.541
37.00	127.014	120.893	109.132	97.458	86.334	70.182
36.50	119.034	113.017	101.527	90.136	79.368	63.821
36.00	111.381	105.469	94.255	83.151	72.743	57.811
35.60	105.487	99.660	88.669	77.798	67.683	53.248
35.00	97.037	91.340	80.688	70.169	60.499	46.820
34.40	89.051	83.485	73.177	63.016	53.797	40.883
34.00	83.980	78.503	68.426	58.507	49.591	37.193
33.50	77.935	72.569	62.784	53.169	44.635	32.888
33.00	72.211	66.958	57.467	48.159	40.011	28.919
32.60	67.849	62.686	53.432	44.371	36.534	25.971
32.00	61.646	56.619	47.724	39.036	31.669	21.904
31.40	55.829	50.941	42.406	34.094	27.201	18.240
31.00	52.159	47.363	39.070	31.011	24.434	16.013
30.50	47.795	43.115	35.126	27.383	21.205	13.460
30.00	43.671	39.108	31.424	23.998	18.220	11.156
29.60	40.544	36.074	28.635	21.465	16.008	9.489
29.00	36.138	31.809	24.738	17.952	12.978	7.281
28.40	32.066	27.879	21.177	14.776	10.287	5.414
28.00	29.535	25.442	18.987	12.844	8.679	4.356

Elevation (m)	Capacity (MCM)					
	2021	10yr	30yr	50yr	70yr	100yr
27.50	26.577	22.602	16.457	10.635	6.875	3.241
27.00	23.852	19.995	14.158	8.660	5.305	2.361
26.60	21.847	18.085	12.496	7.256	4.226	1.834
26.00	19.157	15.536	10.319	5.466	2.923	1.358
25.40	16.812	13.333	8.487	4.021	1.965	0
25.00	15.385	12.001	7.402	3.193	1.462	
24.50	13.730	10.464	6.174	2.287	0.960	
24.00	12.225	9.077	5.095	1.529	0.606	
23.60	11.131	8.076	4.340	1.031	0.431	
23.00	9.661	6.747	3.379	0.453	0.335	
22.40	8.371	5.597	2.596	0.052	0	
22.00	7.595	4.914	2.156	0.039		
21.50	6.713	4.148	1.693	0.026		
21.00	5.925	3.476	1.322	0.013		
20.60	5.360	3.002	1.089	0		
20.00	4.608	2.387	0.832			
19.40	3.950	1.864	0.665			
19.00	3.554	1.559	0.595			
18.50	3.103	1.220	0.548			
18.00	2.698	0.925	0			
17.60	2.405	0.720				
17.00	2.012	0.458				
16.40	1.672	0.247				
16.00	1.471	0.132				
15.50	1.247	0.014				

Elevation (m)	Capacity (MCM)					
	2021	10yr	30yr	50yr	70yr	100yr
15.00	1.050	0.011				
14.60	0.911	0.009				
14.00	0.729	0.007				
13.40	0.575	0.005				
13.00	0.488	0.002				
12.50	0.394	0				
12.00	0.314					
11.60	0.260					
11.00	0.192					
10.40	0.139					
10.00	0.110					
9.50	0.080					
9.00	0.058					
8.60	0.044					
8.00	0.029					
7.40	0.020					
7.00	0.016					
6.50	0.012					
6.00	0.009					
5.60	0.007					
5.00	0.005					
4.40	0.003					
4.00	0.0021					
3.50	0.0013					
3.00	0.0008					

Elevation (m)	Capacity (MCM)					
	2021	10yr	30yr	50yr	70yr	100yr
2.60	0.0004					
2.00	0.00014					
1.40	0.000040					
1.00	0.000017					
0.50	0.000004					
0.00	0.000000					

New zero elevation at every 10 year is given in Table 0-6.

Table 0-6   New zero elevation at every 10 years

Year	New Zero Elevation (m)	Year	New Zero Elevation (m)
10 yr	12.5	60 yr	22
20 yr	16	70 yr	22.4
30 yr	18	80 yr	23.6
40 yr	19.4	90 yr	24.5
50 yr	20.6	100 yr	25.4

It is observed from the study that capacity of reservoir at FRL is reduced from 208.49 MCM to 139.80 MCM in 100 years. Total reservoir capacity at every 10 year is depicted in Figure 0-10.

Figure 0-10   Comparison of reduced reservoir capacity at FRL (10-year interval)

Appendix A: Sample calculation for 30 yr

Determination of Sediment Inflow

Capacity at FRL 41.15 m in 1984 =   234.36 MCM

Capacity at FRL 41.15 m in 2021 =   208.823 MCM

Sediment accumulated in 37 yr = 25.537 MCM

Sediment accumulated per yr = 0.69 MCM

Classification of reservoir

Based on available survey data

Bed Level = 10m

Top Level = 43 m

Total depth of water = 33 m

Plot depth vs capacity on log-log plot

Inverse of slope of the graph (m)

From 17 m slope is predominant m = 3.25

Shape of reservoir (from table) = Floodplain-foothill
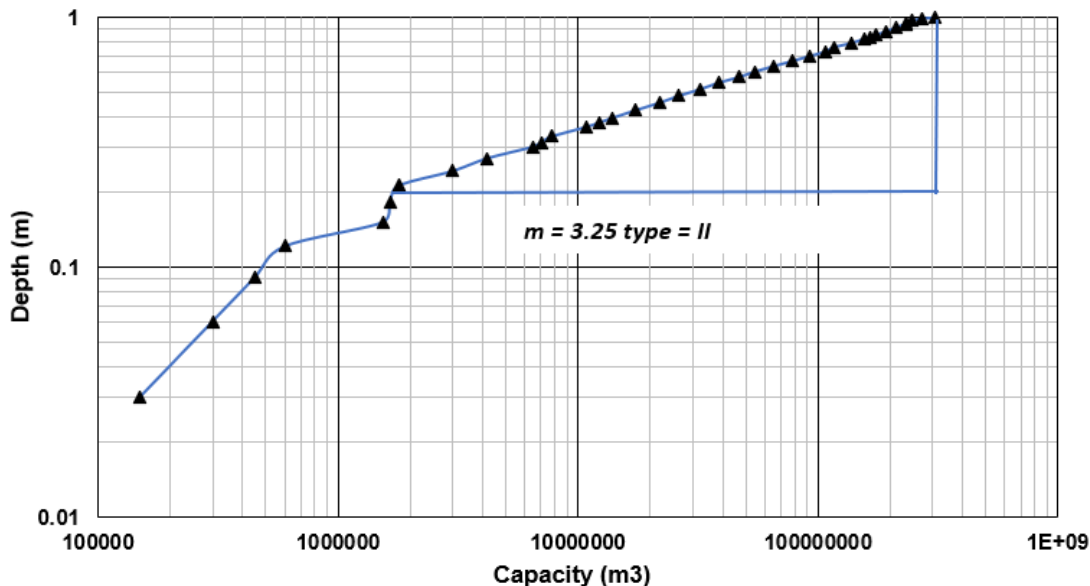
Determination of new zero elevation after 30 years

Total Sediment deposition upto FRL = 0.6902 x 30 = 20.706   MCM

Total sediment deposition upto MWL (S) = 20.706 + computed sediment distribution between 41.15 m and 45.5 m) = 22.57 MCM

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

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

Relative depth at new zero elevation is $p_0 = 0.4$

p_0 is calculated from F vs Relative depth curve sheet.(Figure below)
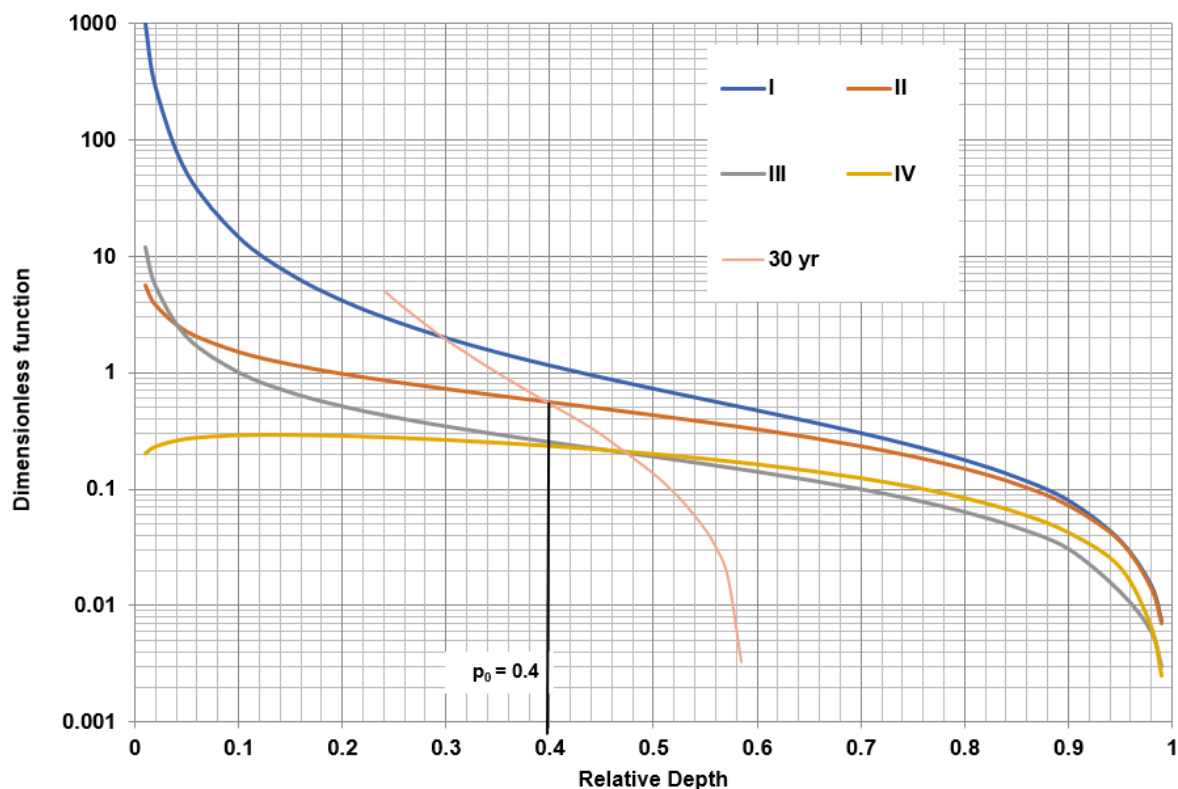
New zero elevation = 18.2 m
Corresponding Area (A0) = 80.14 ha
Distribute Sediment
Type II: $a=2.487p^{0.57}(1-p)^{0.41}$
Relative Sediment area (a) for Type II for $p_0 = 0.4 = 1.196443$
Area correction factor = A0/a = 66.9818 ha

Elevation h, m	Area A, ha	Capacity V_h, 10^6 m^3	F	Relative Depth p	Relative Area a	Computed Sediment Distribution Area, ha	Computed Sediment Distribution Volume Increment, 10^6 m^3	Computed Sediment Distribution Cumulative Volume, 10^6 m^3	Revised Area, ha	Revised Capacity, 10^6 m^3
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
45.5	2918.060	321.641		1.000	0	0.000	0.0651	22.57	2918.060	299.067
45	2843.683	307.237		0.989	0.3888	26.043	0.1180	22.51	2817.640	284.728
44.6	2783.524	295.982		0.980	0.4922	32.972	0.2199	22.39	2750.552	273.591
44	2688.898	279.574		0.967	0.6023	40.341	0.2589	22.17	2648.557	257.403
43.4	2590.066	263.722		0.954	0.6860	45.947	0.1901	21.91	2544.119	241.810
43	2536.704	253.469		0.945	0.7329	49.092	0.2541	21.72	2487.611	231.746

| Elevation h, m | Area A, ha | Capacity V_h, 10^6 m³ | F | Relative | | Computed Sediment Distribution | | | Revised | |
				Depth p	Area a	Area , ha	Volume Increment , 10^6 m³	Cumulative Volume, 10^6 m³	Area , ha	Capacity , 10^6 m³
42.5	2466.861	240.956		0.934	0.7846	52.551	0.2704	21.47	2414.309	219.487
42	2403.685	228.780		0.923	0.8301	55.603	0.2268	21.20	2348.082	207.582
41.6	2353.099	219.266		0.914	0.8631	57.810	0.2653	20.97	2295.289	198.295
41.15	2285.603	208.823		0.904	0.8970	60.083	0.4633	20.71	2225.520	188.117
40.4	2192.456	192.033		0.888	0.9475	63.463	0.2571	20.24	2128.993	171.791
40	2126.726	183.374		0.879	0.9717	65.089	0.3301	19.99	2061.637	163.389
39.5	2048.216	172.939		0.868	0.9998	66.971	0.3392	19.66	1981.246	153.283
39	1966.589	162.896		0.857	1.0257	68.704	0.2774	19.32	1897.885	143.581
38.6	1899.849	155.164		0.848	1.0450	69.995	0.4253	19.04	1829.854	136.125
38	1792.21	144.078		0.835	1.0717	71.785	0.4356	18.61	1720.421	125.465
37.4	1688.10	133.648		0.822	1.0961	73.417	0.2957	18.18	1614.684	115.471
37	1629.66	127.014		0.813	1.1111	74.425	0.3751	17.88	1555.234	109.132
36.5	1562.60	119.034		0.802	1.1287	75.601	0.3807	17.51	1486.997	101.527
36	1499.13	111.381		0.791	1.1449	76.690	0.3084	17.13	1422.443	94.255
35.6	1447.71	105.487		0.782	1.1571	77.503	0.4684	16.82	1370.202	88.669
35	1368.97	97.037		0.769	1.1739	78.630	0.4748	16.35	1290.342	80.688
34.4	1293.59	89.051		0.756	1.1892	79.653	0.3199	15.87	1213.939	73.177
34	1241.75	83.980		0.747	1.1985	80.281	0.4032	15.55	1161.467	68.426
33.5	1176.12	77.935		0.736	1.2094	81.007	0.4067	15.15	1095.117	62.784
33	1113.91	72.211		0.725	1.2193	81.671	0.3277	14.74	1032.243	57.467
32.6	1067.41	67.849		0.716	1.2266	82.159	0.4949	14.42	985.248	53.432
32	1001.07	61.646		0.703	1.2365	82.824	0.4987	13.92	918.249	47.724
31.4	938.10	55.829		0.690	1.2452	83.409	0.3343	13.42	854.694	42.406
31	897.15	52.159		0.681	1.2504	83.757	0.4198	13.09	813.389	39.070

Elevation h, m	Area A, ha	Capacity V_h, 10^6 m³	F	Relative		Computed Sediment Distribution			Revised	
				Depth p	Area a	Area , ha	Volume Increment , 10^6 m³	Cumulative Volume, 10^6 m³	Area , ha	Capacity , 10^6 m³
30.5	848.63	47.80		0.670	1.2562	84.145	0.4216	12.67	764.483	35.126
30	801.12	43.67		0.659	1.2613	84.485	0.3384	12.25	716.634	31.424
29.6	762.54	40.54		0.651	1.2648	84.721	0.5092	11.91	677.821	28.635
29	705.83	36.14		0.637	1.2693	85.019	0.5108	11.40	620.813	24.738
28.4	651.34	32.07		0.624	1.2728	85.251	0.3412	10.89	566.087	21.177
28	614.33	29.54		0.615	1.2745	85.370	0.4271	10.55	528.964	18.987
27.5	568.72	26.58		0.604	1.2762	85.480	0.4276	10.12	483.238	16.457
27	520.57	23.85		0.593	1.2772	85.546	0.3422	9.69	435.026	14.158
26.6	481.60	21.85	0.003	0.585	1.2775	85.568	0.5134	9.35	396.035	12.496
26	414.54	19.16	0.018	0.571	1.2772	85.552	0.5131	8.84	328.986	10.319
25.4	368.90	16.81	0.034	0.558	1.2761	85.477	0.3417	8.32	283.418	8.487
25	345.02	15.38	0.046	0.549	1.2749	85.394	0.4266	7.98	259.621	7.402
24.5	316.64	13.73	0.061	0.538	1.2728	85.254	0.4258	7.56	231.389	6.174
24	285.41	12.23	0.080	0.527	1.2701	85.075	0.3400	7.13	200.335	5.095
23.6	261.98	11.13	0.096	0.519	1.2676	84.903	0.5085	6.79	177.079	4.340
23	228.64	9.66	0.124	0.505	1.2630	84.598	0.5065	6.28	144.043	3.379
22.4	201.91	8.37	0.155	0.492	1.2576	84.237	0.3364	5.78	117.678	2.596
22	186.18	7.60	0.177	0.484	1.2536	83.965	0.4189	5.44	102.217	2.156
21.5	166.74	6.71	0.209	0.473	1.2480	83.591	0.4169	5.02	83.152	1.693
21	148.32	5.93	0.247	0.462	1.2418	83.177	0.3320	4.60	65.145	1.322
20.6	134.25	5.36	0.282	0.453	1.2364	82.819	0.4952	4.27	51.433	1.089
20	116.99	4.61	0.338	0.440	1.2277	82.234	0.4915	3.78	34.753	0.832
19.4	102.94	3.95	0.398	0.426	1.2181	81.593	0.3255	3.28	21.344	0.665
19	94.85	3.55	0.441	0.418	1.2113	81.134	0.4041	2.96	13.719	0.595

Elevation h, m	Area A, ha	Capacity V_h, 10^6 m³	F	Relative		Computed Sediment Distribution			Revised	
				Depth p	Area a	Area, ha	Volume Increment, 10^6 m³	Cumulative Volume, 10^6 m³	Area, ha	Capacity, 10^6 m³
18.5	85.46	3.10	0.501	0.407	1.2022	80.525	0.2410	2.56	4.935	0.548
18.2	**80.14**	**2.86**	**0.541**	**0.400**	**1.1964**	**80.140**	**0.1600**	**2.31**	**0.000**	**0.000**
18	76.71	2.70	0.570	0.396	1.1925	79.876	0.3184	2.15		
17.6	70.00	2.40	0.633	0.387	1.1843	79.327	0.4733	1.84		
17	60.94	2.01	0.742	0.374	1.1713	78.456	0.4679	1.36		
16.4	52.67	1.67	0.872	0.360	1.1574	77.525	0.3088	0.89		
16	47.70	1.47	0.972	0.352	1.1476	76.870	0.3822	0.59		
15.5	42.02	1.25	1.115	0.341	1.1348	76.014	0.3778	0.20		
15	36.83	1.05	1.284	0.330	1.1214	75.113	0.2989	-0.17		
14.6	32.92	0.91	1.446	0.321	1.1102	74.361	0.4426	-0.47		
14	27.86	0.73	1.723	0.308	1.0925	73.178	0.4353	-0.92		
13.4	23.31	0.58	2.074	0.295	1.0738	71.928	0.2860	-1.35		
13	20.45	0.49	2.374	0.286	1.0608	71.056	0.3524	-1.64		
12.5	17.26	0.39	2.824	0.275	1.0439	69.922	0.3466	-1.99		
12	14.51	0.31	3.371	0.264	1.0262	68.736	0.2730	-2.34		
11.6	12.64	0.26	3.879	0.255	1.0115	67.749	0.4019	-2.61		
11	10.07	0.19	4.885	0.242	0.9884	66.204	0.3923	-3.01		
10.4	7.80	0.14	6.326	0.229	0.9641	64.575	0.2560	-3.40		
10	6.61	0.11	7.474	0.220	0.9471	63.442	0.3135	-3.66		
9.5	5.19	0.080	9.518	0.209	0.9251	61.968	0.3060	-3.97		
9	3.89	0.058	12.72	0.198	0.9022	60.428	0.2391	-4.28		
8.6	2.97	0.044	16.66	0.189	0.8830	59.146	0.3488	-4.52		
8	1.90	0.029	26.09	0.176	0.8530	57.134	0.3364	-4.87		
7.4	1.18	0.020	42.12	0.163	0.8212	55.008	0.2171	-5.20		

Elevation h, m	Area A, ha	Capacity V_h, 10^6 m³	F	Relative		Computed Sediment Distribution			Revised	
				Depth p	Area a	Area, ha	Volume Increment, 10^6 m³	Cumulative Volume, 10^6 m³	Area, ha	Capacity, 10^6 m³
7	0.930	0.016	53.30	0.154	0.7990	53.521	0.2628	-5.42		
6.5	0.706	0.012	70.19	0.143	0.7701	51.580	0.2528	-5.68		
6	0.557	0.0090	89.03	0.132	0.7396	49.537	0.1947	-5.94		
5.6	0.454	0.0070	109.22	0.123	0.7140	47.824	0.2788	-6.13		
5	0.334	0.0046	148.47	0.110	0.6734	45.108	0.2619	-6.41		
4.4	0.243	0.0029	204.06	0.097	0.6299	42.192	0.1646	-6.67		
4	0.183	0.0021	270.98	0.088	0.5990	40.120	0.1937	-6.84		
3.5	0.127	0.0013	390.17	0.077	0.5578	37.362	0.1794	-7.03		
3	0.0877	0.00075	565.50	0.066	0.5134	34.386	0.1324	-7.21		
2.6	0.0663	0.00044	748.19	0.057	0.4750	31.814	0.1781	-7.34		
2	0.0368	0.00014	1347.50	0.044	0.4113	27.552	0.1505	-7.52		
1.4	0.0071	0.000040	6953.86	0.031	0.3375	22.610	0.0827	-7.67		
1	0.0041	0.000017	12141.19	0.022	0.2797	18.733	0.0785	-7.75		
0.5	0.0015	0.000004	33905.41	0.011	0.1893	12.677	0.0317	-7.83		
0	0.0002	0.0000001	313614.40	0.000	0	0.000	0.0000	-7.86		

- **Limitation on sediment study:-**

Sediments are deposited in reservoirs at all elevations, causing the stage-capacity curve to shift. Empirical methods have been developed to distribute sediment deposits within a reservoir as a function of depth, thereby projecting the shift in the stage-storage curve. These methods are much quicker and easier to use than mathematical modelingand also require less data. When sediment survey data are available for an existing reservoir, the observed deposition pattern can be used to select the proper empirical relationship to compute the future shift in the stage-area and stage-capacity relationships. As a limitation, empirical methods do not identify the specific locations in a reservoir which will be affected by sediment; they predict only the change in the stage-area and stage-capacity curves. A significant shift in the operating regime, such as implementation of sediment management, will affect the deposition pattern. Empirical methods cannot be user to simulate these effects, and the evaluation of management alternatives requires numerical modeling.

ANNEXURE-II

(BED SAMPLE REPORT)

Bulk Density of the samples:-

Sample - 1

Sand (%)	50.30
Silt (%)	25.70
Clay (%)	24.00
Total (%)	100.00

Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Cont. Submerged	256	91	0	0.85
Periodic drwadown	135	29	0	0.40
Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	W1	W2	W3	W4	W5	W6	W2	W3	W4	W5	W6
Cont. Submerged	966.13	966.27	966.37	966.44	966.5	966.55	966.39	966.53	966.64	966.72	966.79
Periodic drwadown	1006.07	1006.14	1006.18	1006.22	1006.2	1006.27	1006.19	1006.26	1006.31	1006.35	1006.38
Resvr. normally empty	1027.84	1027.84	1027.84	1027.84	1027.8	1027.84	1027.84	1027.84	1027.84	1027.84	1027.84

Where,

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

Sample - 2

Sand (%)	59.66	Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	19.54					
Clay (%)	20.80	Cont. Submerged	256	91	0	0.71
		Periodic drwadown	135	29	0	0.34
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	W1	W2	W3	W4	W5	W6	W2	W3	W4	W5	W6
Cont. Submerged	991.47	991.59	991.67	991.73	991.78	991.82	991.68	991.80	991.89	991.96	992.02
Periodic drwadown	1025.53	1025.59	1025.63	1025.66	1025.7	1025.70	1025.64	1025.70	1025.74	1025.77	1025.80
Resvr. normally empty	1044.13	1044.13	1044.13	1044.13	1044.1	1044.13	1044.13	1044.13	1044.13	1044.13	1044.13

Where,

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

Sample - 3

		Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	28.18					
Silt (%)	38.22					
Clay (%)	33.60	Cont. Submerged	256	91	0	1.21
		Periodic drwadown	135	29	0	0.56
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	W1	W2	W3	W4	W5	W6	W2	W3	W4	W5	W6
Cont. Submerged	891.91	892.11	892.25	892.36	892.44	892.51	892.27	892.49	892.64	892.75	892.85
Periodic drwadown	948.27	948.37	948.43	948.48	948.5	948.56	948.44	948.54	948.61	948.67	948.71
Resvr. normally empty	978.98	978.98	978.98	978.98	979.0	978.98	978.98	978.98	978.98	978.98	978.98

Where,

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

Sample - 4

		Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	26.00					
Silt (%)	37.20					
Clay (%)	36.80	Cont. Submerged	256	91	0	1.28
		Periodic drwadown	135	29	0	0.60
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

Reservoir condition :	Miller's Method							Lane's Method				
	W1	W2	W3	W4	W5	W6		W2	W3	W4	W5	W6
Cont. Submerged	868.73	868.94	869.09	869.20	869.3	869.37		869.11	869.34	869.50	869.62	869.72
Periodic drwadown	929.53	929.63	929.70	929.75	929.8	929.83		929.71	929.82	929.89	929.95	930.00
Resvr. normally empty	962.69	962.69	962.69	962.69	962.7	962.69		962.69	962.69	962.69	962.69	962.69

Where,

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

Sample - 5

		Reservoir condition:		B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	60.00						
Silt (%)	17.60						
Clay (%)	22.40	Cont. Submerged		256	91	0	0.73
		Periodic drwadown		135	29	0	0.35
Total (%)	100.00	Resvr. normally empty		0	0	0	0.00

Reservoir condition :	Miller's Method						Lane's Method				
	W1	W2	W3	W4	W5	W6	W2	W3	W4	W5	W6
Cont. Submerged	980.30	980.43	980.51	980.57	980.63	980.67	980.52	980.65	980.75	980.82	980.87
Periodic drwadown	1016.30	1016.36	1016.40	1016.43	1016.5	1016.48	1016.41	1016.47	1016.52	1016.55	1016.58
Resvr. normally empty	1035.98	1035.98	1035.98	1035.98	1036.0	1035.98	1035.98	1035.98	1035.98	1035.98	1035.98

Where,

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

Sample - 6

		Reservoir condition:		B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	26.80						
Silt (%)	41.20						
Clay (%)	32.00	Cont. Submerged		256	91	0	1.19
		Periodic drwadown		135	29	0	0.55
Total (%)	100.00	Resvr. normally empty		0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	W1	W2	W3	W4	W5	W6	W2	W3	W4	W5	W6
Cont. Submerged	902.76	902.96	903.10	903.20	903.3	903.36	903.12	903.33	903.48	903.59	903.69
Periodic drwadown	957.40	957.49	957.56	957.60	957.6	957.68	957.57	957.66	957.73	957.79	957.83
Resvr. normally empty	987.12	987.12	987.12	987.12	987.1	987.12	987.12	987.12	987.12	987.12	987.12

Where,

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

Sample - 7

		Reservoir condition:		B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	26.00						
Silt (%)	40.40						
Clay (%)	33.60	Cont. Submerged		256	91	0	1.23
		Periodic drwadown		135	29	0	0.57
Total (%)	100.00	Resvr. normally empty		0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W2**	**W3**	**W4**	**W5**	**W6**
Cont. Submerged	891.26	891.46	891.60	891.71	891.8	891.87	891.63	891.84	892.00	892.11	892.21
Periodic drwadown	948.06	948.15	948.22	948.27	948.3	948.34	948.23	948.33	948.40	948.45	948.50
Resvr. normally empty	978.98	978.98	978.98	978.98	979.0	978.98	978.98	978.98	978.98	978.98	978.98

Where,

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

Sample - 8

Sand (%)	49.50	Reservoir condition:		B for Clay	B for Silt	B for Sand	Avg B
Silt (%)	26.50						
Clay (%)	24.00	Cont. Submerged		256	91	0	0.86
		Periodic drwadown		135	29	0	0.40
Total (%)	100.00	Resvr. normally empty		0	0	0	0.00

Reservoir condition :	Miller's Method						Lane's Method				
	W1	W2	W3	W4	W5	W6	W2	W3	W4	W5	W6
Cont. Submerged	965.89	966.03	966.13	966.21	966.3	966.32	966.15	966.30	966.41	966.49	966.56
Periodic drwadown	1005.99	1006.06	1006.10	1006.14	1006.2	1006.19	1006.11	1006.18	1006.23	1006.27	1006.30
Resvr. normally empty	1027.84	1027.84	1027.84	1027.84	1027.8	1027.84	1027.84	1027.84	1027.84	1027.84	1027.84

Where,

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

Sample - 9

Sand (%)	28.00
Silt (%)	40.00
Clay (%)	32.00
Total (%)	100.00

Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Cont. Submerged	256	91	0	1.18
Periodic drwadown	135	29	0	0.55
Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	W1	W2	W3	W4	W5	W6	W2	W3	W4	W5	W6
Cont. Submerged	903.12	903.32	903.45	903.56	903.6	903.71	903.48	903.68	903.83	903.95	904.04
Periodic drwadown	957.52	957.61	957.67	957.72	957.8	957.79	957.68	957.78	957.85	957.90	957.95
Resvr. normally empty	987.12	987.12	987.12	987.12	987.1	987.12	987.12	987.12	987.12	987.12	987.12

Where,

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

Sample - 10

		Reservoir condition:	B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	22.80					
Silt (%)	42.00					
Clay (%)	35.20	Cont. Submerged	256	91	0	1.28
		Periodic drwadown	135	29	0	0.60
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

Reservoir condition :	Miller's Method						Lane's Method				
	W1	W2	W3	W4	W5	W6	W2	W3	W4	W5	W6
Cont. Submerged	879.03	879.25	879.39	879.50	879.6	879.67	879.42	879.64	879.80	879.93	880.03
Periodic drwadown	938.47	938.57	938.64	938.69	938.7	938.77	938.65	938.76	938.83	938.89	938.94
Resvr. normally empty	970.83	970.83	970.83	970.83	970.8	970.83	970.83	970.83	970.83	970.83	970.83

Where,

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

Sample - 11

			B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	28.70	Reservoir condition:				
Silt (%)	34.50					
Clay (%)	36.80	Cont. Submerged	256	91	0	1.26
		Periodic drwadown	135	29	0	0.60
Total (%)	100.00	Resvr. normally empty	0	0	0	0.00

Reservoir condition :	Miller's Method						Lane's Method				
	W1	W2	W3	W4	W5	W6	W2	W3	W4	W5	W6
Cont. Submerged	869.54	869.75	869.89	870.00	870.1	870.17	869.92	870.14	870.29	870.42	870.52
Periodic drwadown	929.80	929.90	929.97	930.02	930.1	930.10	929.98	930.08	930.16	930.22	930.26
Resvr. normally empty	962.69	962.69	962.69	962.69	962.7	962.69	962.69	962.69	962.69	962.69	962.69

Where,

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

Sample - 12

				B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	28.00		Reservoir condition:				
Silt (%)	38.40						
Clay (%)	33.60		Cont. Submerged	256	91	0	1.21
			Periodic drwadown	135	29	0	0.56
Total (%)	100.00		Resvr. normally empty	0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	W1	W2	W3	W4	W5	W6	W2	W3	W4	W5	W6
Cont. Submerged	891.86	892.06	892.20	892.30	892.4	892.46	892.22	892.43	892.58	892.70	892.80
Periodic drwadown	948.26	948.35	948.41	948.46	948.5	948.54	948.43	948.53	948.60	948.65	948.70
Resvr. normally empty	978.98	978.98	978.98	978.98	979.0	978.98	978.98	978.98	978.98	978.98	978.98

Where,

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

Sample - 13

		Reservoir condition:		B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	27.00						
Silt (%)	37.80						
Clay (%)	35.20	Cont. Submerged		256	91	0	1.25
		Periodic drwadown		135	29	0	0.58
Total (%)	100.00	Resvr. normally empty		0	0	0	0.00

	Miller's Method						Lane's Method				
Reservoir condition :	W1	W2	W3	W4	W5	W6	W2	W3	W4	W5	W6
Cont. Submerged	880.29	880.50	880.64	880.75	880.8	880.91	880.67	880.89	881.04	881.16	881.26
Periodic drwadown	938.89	938.99	939.06	939.11	939.1	939.18	939.07	939.17	939.24	939.30	939.35
Resvr. normally empty	970.83	970.83	970.83	970.83	970.8	970.83	970.83	970.83	970.83	970.83	970.83

Where,

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

Sample - 14

		Reservoir condition:		B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	42.00						
Silt (%)	30.80						
Clay (%)	27.20	Cont. Submerged		256	91	0	0.98
		Periodic drwadown		135	29	0	0.46
Total (%)	100.00	Resvr. normally empty		0	0	0	0.00

	Miller's Method							Lane's Method				
Reservoir condition :	W1	W2	W3	W4	W5	W6		W2	W3	W4	W5	W6
Cont. Submerged	941.11	941.28	941.39	941.47	941.5	941.60		941.41	941.58	941.70	941.79	941.87
Periodic drwadown	986.71	986.79	986.84	986.88	986.9	986.94		986.85	986.93	986.99	987.03	987.07
Resvr. normally empty	1011.55	1011.55	1011.55	1011.55	1011.6	1011.55		1011.55	1011.55	1011.55	1011.55	1011.55

Where,

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

Sample - 15

				B for Clay	B for Silt	B for Sand	Avg B
Sand (%)	37.24	Reservoir condition:					
Silt (%)	27.56						
Clay (%)	35.20	Cont. Submerged		256	91	0	1.15
		Periodic drwadown		135	29	0	0.56
Total (%)	100.00	Resvr. normally empty		0	0	0	0.00

	Miller's Method							Lane's Method				
Reservoir condition :	W1	W2	W3	W4	W5	W6		W2	W3	W4	W5	W6
Cont. Submerged	883.36	883.56	883.69	883.79	883.9	883.94		883.71	883.91	884.06	884.17	884.26
Periodic drwadown	939.92	940.01	940.07	940.12	940.2	940.19		940.08	940.18	940.25	940.30	940.35
Resvr. normally empty	970.83	970.83	970.83	970.83	970.8	970.83		970.83	970.83	970.83	970.83	970.83

Where,

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

For Sample-1

Dia (mm)	For Sample-1	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20	-	20				
D30	0.005	30				
D40	0.015	40	10	0.009	0.088	-1.056
D50	0.075	50	10	0.033	0.332	-0.479
D60	0.380	60	10	0.169	1.688	0.227
D70	0.560	70	10	0.461	4.613	0.664
D80	1.400	80	10	0.885	8.854	0.947
D90	5.600	90	10	2.800	28.000	1.447
D100	6.300	100	10	5.940	59.397	1.774
D84	1.600	84				
D16	-	16				

da   1.471   mm

dg   1.085   mm

σg   -

M   0.004

Remarks: Sediment is non-uniform

Where,

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

For Sample-2

Dia (mm)	For Sample-2	p	Δp	di	dixΔp	log(dixΔp)
D0	-	0				
D10	-	10				
D20	-	20				
D30	0.009	30				
D40	0.057	40	10	0.022	0.220	-0.658
D50	0.500	50	10	0.169	1.686	0.227
D60	5.600	60	10	1.673	16.733	1.224
D70	6.300	70	10	5.940	59.397	1.774
D80	7.000	80	10	6.641	66.408	1.822
D90	8.500	90	10	7.714	77.136	1.887
D100	10.000	100	10	9.220	92.195	1.965
D84	7.400	84				
D16	-	16				

da   4.483   mm

dg   1.209   mm

σg   -

M   0.006

Remarks: Sediment is non-uniform

Where,

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

For Sample-3

Dia (mm)	For Sample-3	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10	-	10				
D20	-	20				
D30	-	30				
D40	0.004	40				
D50	0.044	50	10	0.014	0.138	-0.862
D60	5.600	60	10	0.496	4.964	0.696
D70	6.300	70	10	5.940	59.397	1.774
D80	7.000	80	10	6.641	66.408	1.822
D90	8.500	90	10	7.714	77.136	1.887
D100	10.000	100	10	9.220	92.195	1.965
D84	7.400	84				
D16	-	16				

da   5.004   mm

dg   1.183   mm

σg   -

M   0.0005

Remarks: Sediment is Non - uniform

Where,

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

For Sample-4

Dia (mm)	For Sample-4	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10	-	10				
D20	-	20				
D30	-	30	10			
D40	0.002	40	10			
D50	0.014	50	10	0.005	0.054	-1.270
D60	0.068	60	10	0.031	0.313	-0.504
D70	0.073	70	10	0.070	0.705	-0.152
D80	0.054	80	10	0.063	0.628	-0.202
D90	5.300	90	10	0.535	5.350	0.728
D100	6.300	100	10	5.778	57.784	1.762
D84	0.700	84				
D16	-	16				

da   1.0806   mm

dg   1.008   mm

σg   -

M   0.001

Remarks: Sediment is non-uniform

Where,

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

For Sample-5

Dia (mm)	For Sample-5	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20	-	20				
D30	0.011	30				
D40	0.075	40	10	0.028	0.281	-0.551
D50	0.460	50	10	0.186	1.857	0.269
D60	4.000	60	10	1.356	13.565	1.132
D70	6.300	70	10	5.020	50.200	1.701
D80	8.100	80	10	7.144	71.435	1.854
D90	9.000	90	10	8.538	85.381	1.931
D100	10.000	100	10	9.487	94.868	1.977
D84	8.600	84				
D16	-	16				

da   4.537   mm

dg   1.211   mm

σg

M   0.007

Remarks: Sediment is Non - uniform

Where,

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

For Sample-6

Dia (mm)	For Sample-6	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10	-	10				
D20	-	20				
D30	-	30	10			
D40	0.005	40	10			
D50	0.060	50	10	0.018	0.176	-0.753
D60	0.068	60	10	0.064	0.639	-0.195
D70	0.074	70	10	0.071	0.709	-0.149
D80	0.320	80	10	0.154	1.539	0.187
D90	4.000	90	10	1.131	11.314	1.054
D100	5.600	100	10	4.733	47.329	1.675
D84	0.500	84				
D16	-	16				

da   1.028   mm

dg   1.043   mm

σg

M   0.003

Remarks: Sediment is non -uniform

Where,

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

For Sample-7

Dia (mm)	For Sample-7	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20	-	20				
D30	-	30				
D40	0.004	40				
D50	0.050	50	10	0.015	0.148	-0.829
D60	0.068	60	10	0.058	0.583	-0.234
D70	0.072	70	10	0.070	0.700	-0.155
D80	0.500	80	10	0.190	1.897	0.278
D90	5.300	90	10	1.628	16.279	1.212
D100	6.300	100	10	5.778	57.784	1.762
D84	2.000	84				
D16	-	16				

da   1.290   mm

dg   1.048   mm

σg

M   0.002

Remarks: Sediment is non - uniform

Where,

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

For Sample-8

Dia (mm)	For Sample-8	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10		10				
D20	-	20				
D30	0.046	30				
D40	0.015	40	10	0.026	0.263	-0.581
D50	0.075	50	10	0.034	0.335	-0.474
D60	0.130	60	10	0.099	0.987	-0.005
D70	0.240	70	10	0.177	1.766	0.247
D80	0.052	80	10	0.112	1.117	0.048
D90	5.300	90	10	0.525	5.250	0.720
D100	6.300	100	10	5.778	57.784	1.762
D84	2.000	84				
D16	-	16				

da   0.964   mm

dg   1.040   mm

σg

M   0.009

Remarks: Sediment is non-uniform

Where,

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

For Sample-9

Dia (mm)	For Sample-9	p	Δp	di	di×Δp	log(di×Δp)
D0		0				
D10	-	10				
D20	-	20				
D30	-	30				
D40	0.007	40				
D50	0.047	50	10	0.019	0.186	-0.731
D60	0.068	60	10	0.057	0.565	-0.248
D70	0.074	70	10	0.071	0.709	-0.149
D80	1.500	80	10	0.333	3.332	0.523
D90	5.300	90	10	2.820	28.196	1.450
D100	6.300	100	10	5.778	57.784	1.762
D84	2.000	84				
D16		16				

da   1.513   mm

dg   1.062   mm

σg

M   0.002

Remarks: Sediment is non - uniform

Where,

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

For Sample-10

Dia (mm)	For Sample-10	p	Δp	di	dixΔp	log(dixΔp)
D0		0				
D10	-	10				
D20	-	20				
D30	-	30				
D40	0.0030	40				
D50	0.0230	50	10	0.008	0.083	-1.081
D60	0.0650	60	10	0.039	0.387	-0.413
D70	0.0700	70	10	0.067	0.675	-0.171
D80	0.0380	80	10	0.052	0.516	-0.288
D90	5.3000	90	10	0.449	4.488	0.652
D100	6.3000	100	10	5.778	57.784	1.762
D84	3.0000	84				
D16	-	16				

d_a 1.066   mm

d_g 1.011   mm

σ_g -

M   0.001

Remarks: Sediment is non - uniform

Where,

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

For Sample-11

Dia (mm)	For Sample-11	p	Δp	di	dixΔp	log(dixΔp)
D0	-	0				
D10	-	10				
D20	-	20				
D30	-	30				
D40	0.00250	40				
D50	0.03000	50	10	0.009	0.087	-1.062
D60	0.06800	60	10	0.045	0.452	-0.345
D70	0.07400	70	10	0.071	0.709	-0.149
D80	0.34000	80	10	0.159	1.586	0.200
D90	5.30000	90	10	1.342	13.424	1.128
D100	6.30000	100	10	5.778	57.784	1.762
D84	2.00000	84				
D16	-	16				

da   1.234   mm

dg   1.036   mm

σg   -

M   0.001

Remarks: Sediment is non - uniform

Where,

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

For Sample-12

Dia (mm)	For Sample-12	p	Δp	di	dixΔp	log(dixΔp)
D0	-	0				
D10	-	10				
D20	-	20				
D30	-	30				
D40	0.0052	40				
D50	0.048	50	10	0.016	0.158	-0.801
D60	0.069	60	10	0.058	0.575	-0.240
D70	0.074	70	10	0.071	0.715	-0.146
D80	0.092	80	10	0.083	0.825	-0.083
D90	5.3	90	10	0.698	6.983	0.844
D100	6.3	100	10	5.778	57.784	1.762
D84	3	84				
D16	-	16				

da   1.117   mm

dg   1.031   mm

σg   -

M   0.002

Remarks: Sediment is non - uniform

Where,

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

For Sample-13

Dia (mm)	For Sample-13	p	Δp	di	dixΔp	log(dixΔp)
D0	-	0				
D10	-	10				
D20	-	20				
D30	-	30				
D40	0.0037	40				
D50	0.037	50	10	0.012	0.117	-0.933
D60	0.067	60	10	0.050	0.498	-0.303
D70	0.072	70	10	0.069	0.695	-0.158
D80	0.40	80	10	0.170	1.697	0.230
D90	5.30	90	10	1.456	14.560	1.163
D100	6.30	100	10	5.778	57.784	1.762
D84	1.20	84				
D16	-	16				

da   1.256   mm

dg   1.041   mm

σg   -

M   0.002

Remarks: Sediment is non - uniform

Where,

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

For Sample-14

Dia (mm)	For Sample-14	p	Δp	di	dixΔp	log(dixΔp)
D0	-	0				
D10	-	10				
D20	-	20				
D30	0.0037	30				
D40	0.0090	40	10	0.006	0.058	-1.237
D50	0.0230	50	10	0.014	0.144	-0.842
D60	0.1000	60	10	0.048	0.480	-0.319
D70	0.2800	70	10	0.167	1.673	0.224
D80	0.6000	80	10	0.410	4.099	0.613
D90	5.6000	90	10	1.833	18.330	1.263
D100	6.3000	100	10	5.940	59.397	1.774
D84	0.7200	84				
D16	-	16				

da   1.203   mm

dg   1.035   mm

σg   -

M   0.002

Remarks: Sediment is non - uniform

Where,

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

For Sample-15

Dia (mm)	For Sample-15	p	Δp	di	dixΔp	log(dixΔp)
D0	-	0				
D10	-	10				
D20	-	20				
D30	-	30				
D40	0.005	40				
D50	0.056	50	10	0.017	0.170	-0.768
D60	0.072	60	10	0.063	0.635	-0.197
D70	0.170	70	10	0.111	1.106	0.044
D80	0.500	80	10	0.292	2.915	0.465
D90	5.300	90	10	1.628	16.279	1.212
D100	6.300	100	10	5.778	57.784	1.762
D84	2.000	84				
D16	-	16				

da   1.315   mm

dg   1.060   mm

σg   -

M   0.002

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

ANNEXURE-III

(DATA)

Table-I

- **Inflow at Salaulim Dam:-**

Inflow - 1983-85		Inflow - 1983-85	
Time in Hrs	Inflow (M3/sec)	Time in Hrs	Inflow (M3/sec)
0	28.16	36	3229.32
1	55.62	37	3729.4
2	121.73	38	3518.74
3	201.7	39	2898.52
4	267.01	40	2281.08
5	315.55	41	1799.41
6	349.38	42	1439.33
7	373.36	43	1167.2
8	416.53	44	958.98
9	391.94	45	805.91
10	448.71	46	696.83
11	478.59	47	617.95
12	511.79	48	546.66
13	550.07	49	452.82
14	582.7	50	843.93
15	607.99	51	252.43
16	637.35	52	186.08
17	672.92	53	139.05
18	703.6	54	105.72
19	727.53	55	82.07
20	755.91	56	65.26
21	790.78	57	53.31
22	820.99	58	44.69
23	842.99	59	38.47
24	858.59	60	33.86
25	869.61	61	30.95
26	877.41	62	29.1
27	886.1	63	27.84
28	915.11	64	26.95
29	965.17	65	26.33
30	1014.8	66	25.89
31	1088.31	67	25.89
32	1208.31	68	25.38
33	1433.65	69	25.22
34	1826.88	70	25.12
35	2438.22		

Table-IA

- **Outflow at Salaulim Dam:-**

Outflow - 1983-85	
Time in Hrs	**Outflow (M3/sec)**
0	30
12	80
18	240
24	460
30	610
33	640
36	750
37	960
38	1160
39	1310
40	1400
41	1440
42	1460
43	1450
44	1420
45	1380
46	1340
47	1290
48	1240
49	1100
50	1120
51	1060
52	870
53	710
60	670
66	610

Table-I B

- **Peak flow at Salaulim Dam:-**

Sr. No	Dates	Peak Flow (m3/Sec)
1	19.07.83 to 28.07.83	510.00
2	6.08.83 to 17.08.83	780.00
3	29.06.84 to 06.07.84	485.00
4	14.07.84 to 21.07.84	452.00
5	31.07.84 to 05.08.84	405.00
6	24.06.85 to 29.06.85	572.00
7	30.07.85 to 05.08.85	452.00

Table 7 - Peak Flow of Salaulim Dam in different year

Table-II

- **Reservoir Level of Salaulim Dam in different year:-**

Reservoir Level -1983-85		Reservoir Level -1983-85	
Time Hrs	Reservoir level (m)	Time Hrs	Reservoir level (m)
0	41.15	43	45.49
12	41.77	44	45.44
18	42.20	45	45.36
24	42.73	46	45.27
30	43.09	47	45.17
33	43.36	48	45.07
36	44.11	49	44.97
37	44.52	50	44.85
38	44.92	51	44.72
39	45.21	52	44.35
40	45.40	53	44.01
41	45.49	60	43.70
42	45.51	66	43.10

Table 8- Reservoir Level of Salaulim Dam

- **Maximum Discharge at Spillway:-**

Sl. No.	Year	Day/Month	Max Discharge at Spillway in Cumecs
1	2014	31-Aug	141.3542
2	2015	18-Sept	111.7014
3	2016	26-Sept	101.5856
4	2017	28-Aug	74.9884
5	2018	14-Aug	125.5208
6	2019	07-Aug	188.6533
7	2020	11-Aug	190.3265

- **Table showing the Average Discharge in the Main canal and average RL of water storage of the dam of SIP for the year 2014:-**

No.	Month/Year	Average RL	Average Discharge		Total discharge per month in Million cum
			In Cumecs	In MLD	
1	January'2014	39.785	7.44	642.82	19.93
2	February'2014	38.260	7.55	652.32	18.26
3	March'2014	36.370	8.87	766.37	23.76
4	April'2014	34.215	8.68	749.95	22.50
5	May'2014	32.345	4.27	368.93	11.44
6	June'2014	32.375	1.78	153.79	4.61
7	July'2014	37.640	0.87	75.17	2.33
8	August'2014	42.345	1.00	86.40	2.68
9	September'2014	41.850	1.42	122.69	3.68
10	October'2014	41.360	1.53	132.19	4.10
11	November'2014	41.220	1.10	95.04	2.85
12	December'2014	40.795	2.19	189.22	5.87

- **Table showing the Average Discharge in the Main canal and average RL of water storage of the dam of SIP for the year 2015:-**

No.	Month/Year	Average RL	Average Discharge		Total discharge per month in Million cum
			In Cumecs	**In MLD**	
1	January'2015	39.805	4.90	423.36	13.12
2	February'2015	38.255	7.30	630.72	17.66
3	March'2015	36.080	8.50	734.40	22.77
4	April'2015	34.725	6.97	602.21	18.07
5	May'2015	32.930	4.13	356.83	11.06
6	June'2015	33.620	1.90	164.16	4.92
7	July'2015	38.500	1.00	86.40	2.68
8	August'2015	41.680	1.00	86.40	2.68
9	September'2015	41.440	0.93	80.35	2.41
10	October'2015	41.255	0	0	0
11	November'2015	41.110	0	0	0
12	December'2015	40.595	3.84	331.78	10.29

- **Table showing the Average Discharge in the Main canal and average RL of water storage of the dam of SIP for the year 2016:-**

No.	Month/Year	Average RL	Average Discharge		Total discharge per month in Million cum
			In Cumecs	**In MLD**	
1	January'2016	39.390	6.98	603.07	18.70
2	February'2016	37.830	7.12	615.17	17.84
3	March'2016	35.970	9.40	812.16	25.18
4	April'2016	33.805	7.85	678.24	20.35
5	May'2016	31.805	5.92	511.49	15.86
6	June'2016	32.665	2.90	250.56	7.52
7	July'2016	38.300	2.00	172.80	5.36
8	August'2016	41.625	2.00	172.80	5.36
9	September'2016	41.605	2.00	172.80	5.18
10	October'2016	41.415	1.54	133.06	4.12
11	November'2016	41.080	0	0	0
12	December'2016	40.555	3.18	274.75	8.52

- **Table showing the Average Discharge in the Main canal and average RL of water storage of the dam of SIP for the year 2017:-**

No.	Month/Year	Average RL	Average Discharge		Total discharge per month in Million cum
			In Cumecs	**In MLD**	
1	January'2017	39.385	6.84	590.98	18.32
2	February'2017	37.790	6.96	601.34	16.84
3	March'2017	35.860	8.74	755.14	23.41
4	April'2017	33.495	9.15	790.56	23.72
5	May'2017	31.165	5.54	478.66	14.84
6	June'2017	31.285	1.98	171.07	5.13
7	July'2017	37.150	1.50	129.60	4.02
8	August'2017	41.655	1.50	129.60	4.02
9	September'2017	41.705	0.55	47.52	1.43
10	October'2017	41.485	0	0	0
11	November'2017	41.150	0	0	0
12	December'2017	40.695	3.58	309.31	9.59

- **Table showing the Average Discharge in the Main canal and average RL of water storage of the dam of SIP for the year 2018:-**

No.	Month/Year	Average RL	Average Discharge		Total discharge per month in Million cum
			In Cumecs	In MLD	
1	January'2018	39.560	8.38	724.03	22.44
2	February'2018	38.000	8.18	706.75	19.79
3	March'2018	36.175	8.48	732.67	22.71
4	April'2018	33.950	8.67	749.09	22.47
5	May'2018	31.855	5.12	442.37	13.71
6	June'2018	33.365	2.20	190.08	5.70
7	July'2018	38.745	1.16	100.22	3.11
8	August'2018	41.620	1.00	86.40	2.68
9	September'2018	41.470	1.05	90.72	2.72
10	October'2018	41.195	0.19	16.42	0.51
11	November'2018	41.090	0	0	0
12	December'2018	40.520	3.24	279.94	8.68

- **Table showing the Average Discharge in the Main canal and average RL of water storage of the dam of SIP for the year 2019:-**

No.	Month/Year	Average RL	Average Discharge		Total discharge per month in Million cum
			In Cumecs	**In MLD**	
1	January 2019	39.135	5.69	491.62	15.24
2	February 2019	37.410	9.00	777.60	21.77
3	March 2019	36.360	9.82	848.45	26.30
4	April 2019	32.855	9.87	852.77	25.58
5	May 2019	30.245	5.65	488.16	15.13
6	June 2019	29.970	2.53	218.59	6.56
7	July 2019	36.905	1.50	129.60	4.02
8	August 2019	41.820	1.06	91.58	2.84
9	September 2019	41.595	2.00	172.80	5.18
10	October 2019	41.480	2.24	193.54	6.00
11	November 2019	41.340	1.0	86.40	2.59
12	December 2019	40.890	3.65	315.36	9.78

- **Table showing the Average Discharge in the Main canal from Head Regulator and average RL of water storage of the dam of SIP for the year 2020:-**

No.	Month/Year	Average RL	Average Discharge		Total discharge per month in Million cum
			In Cumecs	**In MLD**	
1	January 2020	39.865	9.03	780.19	24.19
2	February 2020	38.350	9.50	820.80	23.80
3	March 2020	36.560	10.58	914.11	28.34
4	April 2020	34.495	10.23	883.87	26.52
5	May 2020	32.430	7.34	634.18	19.66
6	June 2020	33.495	3.28	283.39	8.50
7	July 2020	38.850	2.50	216.00	6.70
8	August 2020	41.825	2.50	216.00	6.70
9	September 2020	41.770	1.75	151.20	4.54
10	October 2020	41.465	0	0	0
11	November 2020	41.205	0	0	0

- **Domestic Water Supply:-**

  (Quantity as per actual raw water drawn from SIP reservoir)

Year	160 MLD (PWD)	100 MLD (JICA)	Total (in MLD)
2014-15	208.62	-	208.62
2015-16	223.46	-	223.46
2016-17	222.09	13.02 (plant commissioned in October 2016. Averaged for the whole year)	235.11
2017-18	183.32	74.33	257.65
2018-19	179.88	91.28	271.16
2019-20	181.54	96.65	278.19
2020-21	174.50 (upto November 2020)	98.03 (upto September 2020)	

- **Maximum Water level Year wise:-**

S. No.	Year	Day/Month	R.L.
1	2013	25-Jul	42.70
2	2014	31-Aug	42.50
3	2015	18-Sep	42.12
4	2016	26-Sep	42.10
5	2017	28-Aug	41.91
6	2018	14-Aug	42.28
7	2019	7-Aug	42.65
8	2020	11-Aug	42.67

- **Minimum Water level Year wise:-**

S. No.	Year	Day/Month	R.L.
1	2013	30-May	32.56
2	2014	16-Jun	31.06
3	2015	12-Jun	31.62
4	2016	10-Jun	30.60
5	2017	9-Jun	29.87
6	2018	10-Jun	30.78
7	2019	12-Jun	28.26
8	2020	2-Jun	31.36

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

Sl. No.	Date	Minimum W.L (m)	Maximum W.L (m)
1	23.01.2021	39.305	39.378
2	24.01.2021	39.257	39.325
3	25.01.2021	39.223	39.300
4	26.01.2021	39.144	39.261
5	27.01.2021	39.171	39.224
6	28.01.2021	39.113	39.208
7	29.01.2021	39.063	39.099
8	30.01.2021	38.996	39.035
9	31.01.2021	39.014	39.061
10	01.02.2021	38.946	38.986
11	02.02.2021	38.906	38.974

Table 9-Minimum & Maximum Water level in the year 2021

- **Salaulim Reservoir 100 MLD (Water Treatment Plant) Withdrawal data:-**

Withdrawal of raw water from SIP Reservoir at 100 MLD water Treatment Plant	
Month & Year	**Quantity of Raw water withdrawal (in MLD)**
Oct-16	604.60
Nov-16	648.60
Dec-16	771.50
Jan-17	833.60
Feb-17	848.12
Mar-17	1044.60
Apr-17	1157.10
May-17	1597.41
Jun-17	2006.70
Jul-17	2298.08
Aug-17	2201.17
Sep-17	2237.28
Oct-17	2379.90
Nov-17	2631.82
Dec-17	2699.57
Jan-18	2746.93
Feb-18	2545.51
Mar-18	2629.40
Apr-18	2460.13
May-18	2576.49
Jun-18	2969.29
Jul-18	2746.18
Aug-18	2743.16
Sep-18	2654.76
Oct-18	2791.40
Nov-18	3058.29
Dec-18	2993.71
Jan-19	2605.26
Feb-19	2547.49
Mar-19	3170.76
Apr-19	3073.50
May-19	3198.19
Jun-19	2866.31
Jul-19	2722.89
Aug-19	2747.00

Table 10-Salaulim Reservoir 100 MLD (Water Treatment Plant) Withdrawal data

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2000:-**

Date	January	February	March	April	May	June	July	August	September	October	November	December
	Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2000											
1	158.62	178.25	171.71	172.70	191.62	177.43	159.83	161.70	160.98	143.16	48.89	171.60
2	164.39	179.74	168.63	175.45	200.47	179.30	159.50	162.80	165.33	159.00	151.85	168.63
3	165.49	178.31	131.39	187.00	191.89	175.01	159.83	162.91	154.49	157.68	162.14	168.52
4	166.65	180.89	174.9	185.35	200.36	165.27	157.74	159.94	161.15	163.07	164.06	171.87
5	167.36	169.4	172.15	181.83	173.25	159.83	166.10	160.76	158.51	161.75	169.45	171.65
6	116.82	158.84	172.09	183.15	188.70	160.93	156.64	163.29	157.46	149.93	165.44	168.52
7	13.2	177.59	173.03	190.79	188.54	168.63	158.73	157.90	166.10	155.10	167.80	167.64
8	149.87	174.35	176.49	187.33	195.25	182.65	156.33	170.99	162.08	156.42	167.36	171.10
9	164.39	177.59	173.96	186.12	198.33	176.00	155.43	158.40	152.90	157.46	165.60	170.72
10	165	176.44	177.15	187.22	195.25	173.85	153.50	76.28	156.20	155.43	164.12	168.52
11	167.42	173.91	173.96	180.78	195.25	138.05	147.40	24.80	158.84	153.01	164.39	168.68
12	173.14	176.44	179.46	188.59	199.21	153.39	146.63	101.47	162.91	161.86	161.70	171.76
13	171.87	172.81	177.43	189.20	195.80	160.93	139.20	158.89	158.40	162.19	162.91	179.74
14	168.68	175.5	178.31	193.10	194.04	158.73	158.40	159.77	155.15	156.69	166.10	19.85
15	143.05	175.5	173.80	189.75	194.15	156.75	155.59	153.23	159.83	157.79	166.26	33.33
16	154.05	172.2	174.13	193.10	186.50	158.95	154.33	146.90	160.60	161.97	160.76	137.88
17	163.02	178.75	175.01	196.90	181.94	158.62	161.04	147.84	162.85	101.69	168.85	173.30
18	151.08	163.29	173.96	175.06	202.40	150.86	156.75	162.25	165.38	159.66	167.80	172.09
19	162.91	179.96	166.26	193.10	197.50	153.17	158.62	160.71	158.56	157.52	160.82	169.40
20	167.69	123.31	177.26	195.91	195.08	153.23	158.73	159.50	40.97	153.34	167.25	174.40
21	165.22	19.25	175.12	193.71	109.39	154.11	165.22	158.56	76.01	157.74	170.88	168.68
22	169.78	75.24	176.11	198.11	188.26	156.47	152.95	155.59	164.28	156.47	158.67	171.60
23	166.48	176.55	176.60	192.50	183.92	167.20	157.63	147.51	161.81	148.77	157.79	173.08
24	168.46	180.84	176.00	192.00	171.98	164.45	162.25	118.30	155.26	158.73	168.85	171.82
25	171.82	176.33	174.18	184.19	177.43	164.45	164.17	151.91	159.50	146.68	172.15	172.70
26	174.9	168.68	175.17	197.01	165.38	163.29	157.41	150.70	128.70	151.08	173.80	176.38
27	169.56	141.24	174.13	197.28	184.19	161.15	157.90	153.28	156.69	155.15	168.68	172.92
28	170.66	167.31	175.45	200.69	188.21	161.86	157.35	164.01	157.30	159.83	166.54	177.10
29	170.61	163.02	175.12	199.70	185.18	158.62	161.97	160.05	152.90	161.09	171.82	175.23
30	176.16		178.42	200.42	160.98	155.43	159.94	163.02	156.47	168.41	166.54	175.06
31	176.44		179.79		167.75		162.80	164.17		66.38		166.70
	4934.79	**4711.53**	**5377.17**	**5688.04**	**5748.20**	**4868.61**	**4879.91**	**4597.43**	**4547.61**	**4715.05**	**4849.27**	**5000.47**

Table 11-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2000

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2001:-**

Date	January	February	March	April	May	June	July	August	September	October	November	December
					Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2001							
1	168.85	172.70	185.24	182.98	187.60	187.33	167.42	8.80	165.38	-	175.45	166.26
2	163.24	175.28	184.30	184.08	188.26	179.52	169.51	47.46	168.57	163.07	178.47	160.87
3	168.68	174.07	183.70	184.80	146.90	176.27	164.50	143.60	166.65	173.91	171.71	171.82
4	167.42	172.09	180.40	181.88	173.14	180.56	157.79	161.97	166.65	169.45	175.28	167.53
5	168.63	173.14	181.50	183.70	190.35	172.15	160.65	160.60	169.62	167.53	172.75	170.66
6	147.73	178.31	185.35	185.90	181.50	147.62	159.94	162.85	167.64	159.94	175.23	168.90
7	169.95	177.26	190.41	184.80	187.22	169.67	160.05	161.86	166.21	163.24	166.70	170.50
8	168.46	176.33	188.43	184.08	184.14	184.25	144.26	160.76	167.64	164.23	172.70	169.45
9	165.11	154.44	185.40	184.80	185.02	180.95	162.96	164.23	168.41	168.52	169.67	171.76
10	161.86	166.70	193.93	183.70	185.13	172.09	159.66	163.13	164.39	171.65	172.97	172.15
11	167.42	171.76	189.20	182.87	195.08	160.71	162.30	165.36	163.40	165.22	170.00	171.87
12	169.45	175.12	187.44	177.65	183.86	167.75	166.26	159.55	171.98	159.00	169.95	175.28
13	173.30	174.24	20.40	167.53	181.00	140.85	158.78	159.00	174.07	158.56	171.60	171.71
14	164.17	170.55	114.40	160.71	189.31	157.90	158.67	160.87	172.81	145.75	173.96	173.19
15	166.70	178.31	169.89	168.85	196.29	165.33	159.72	160.05	172.04	161.20	169.40	170.00
16	165.49	173.08	177.21	170.83	192.88	152.24	153.45	127.93	172.04	161.70	176.11	141.19
17	170.00	174.90	189.64	178.53	189.36	169.78	159.50	157.57	177.59	162.80	170.00	164.22
18	167.58	176.11	184.40	183.09	192.94	172.15	153.45	156.80	169.40	158.56	162.03	159.88
19	170.61	165.11	185.95	175.23	195.03	172.75	161.04	155.10	170.05	164.39	168.35	163.02
20	167.36	178.36	189.69	174.24	191.78	169.84	163.90	161.70	172.86	165.38	173.85	163.18
21	168.79	169.51	191.45	190.63	193.10	171.60	162.80	160.60	176.22	162.30	174.13	160.10
22	169.62	166.43	188.32	186.12	187.27	173.91	159.00	163.35	175.28	159.66	168.74	162.85
23	167.53	185.40	177.48	133.43	186.45	167.58	175.12	160.98	171.71	160.71	169.45	163.35
24	84.20	181.77	191.51	93.72	162.25	175.34	165.38	157.35	176.55	167.64	169.89	173.85
25	153.06	178.31	187.49	155.43	164.34	174.13	167.47	168.30	169.45	167.31	181.88	167.31
26	175.17	178.25	189.58	165.11	182.10	177.10	163.18	165.27	169.78	165.11	169.89	170.00
27	173.03	180.67	186.39	168.46	177.21	176.60	158.45	164.06	166.26	162.80	168.68	169.45
28	155.32	169.67	183.97	170.83	179.90	160.60	161.86	170.50	163.29	166.48	168.46	167.58
29	173.30		183.94	174.90	173.08	171.98	161.86	168.30	172.97	172.04	170.00	165.16
30	170.94		183.97	166.10	187.05	167.25	163.18	168.57	163.07	172.81	171.93	164.50
31	175.23		184.80		180.84		134.36	169.84		173.03		168.46
	5098.2	4867.87	5515.78	5184.98	5690.38	5095.8	4976.47	4716.31	5091.98	4933.99	5149.23	5176.05

Table 12-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2001

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2002:-**

Date	January	February	March	April	May	June	July	August	September	October	November	December
Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2002												
1	165.27	176.22	183.86	195.85	194.75	185.29	181.50	166.37	157.90	173.14	147.56	163.95
2	158.40	177.37	183.20	192.61	195.85	181.77	169.73	163.40	154.60	159.66	160.87	160.60
3	164.23	181.50	184.25	193.87	194.86	183.20	178.20	160.87	155.15	168.85	155.15	159.88
4	172.09	181.00	183.09	173.19	200.20	174.07	179.57	148.61	156.58	165.33	148.72	160.87
5	172.15	173.03	180.95	194.15	203.50	172.09	183.20	158.56	155.48	137.77	157.85	161.04
6	172.86	179.41	173.25	203.50	196.29	191.89	180.89	154.00	158.40	164.12	160.60	161.09
7	176.33	179.30	159.77	191.84	200.75	188.26	179.57	157.35	162.80	158.62	157.63	161.04
8	165.55	167.36	179.68	193.71	202.89	178.47	179.79	150.81	161.97	126.72	157.63	160.98
9	162.19	178.69	183.97	161.86	201.35	171.60	180.67	157.57	160.93	158.56	152.35	161.09
10	167.80	176.38	146.46	199.10	193.98	190.90	178.80	157.79	164.50	141.29	155.59	162.30
11	167.20	182.65	178.25	182.87	203.94	188.37	178.69	152.29	163.95	152.40	159.83	162.96
12	174.07	179.52	188.37	191.73	193.71	178.64	175.01	154.33	166.10	155.32	159.50	161.81
13	171.87	178.20	191.78	192.99	198.49	186.17	175.01	155.21	162.14	159.55	17.10	165.16
14	165.33	184.80	197.50	196.07	194.09	178.58	168.30	158.84	161.09	153.12	166.59	169.73
15	165.60	184.19	196.90	192.99	203.61	174.02	168.63	157.63	162.85	162.96	173.80	169.95
16	160.10	178.47	193.98	198.38	188.15	175.01	168.63	156.25	161.75	161.86	174.07	167.36
17	165.05	185.35	192.61	200.20	199.48	137.61	177.32	152.90	150.86	159.88	167.75	166.54
18	165.44	180.56	191.76	188.15	191.73	132.16	178.36	153.45	168.46	162.91	171.87	164.06
19	164.06	175.28	192.94	180.67	186.12	169.45	177.54	158.51	172.04	164.34	173.14	166.37
20	166.21	185.40	195.91	186.06	200.75	154.55	177.48	161.70	169.56	163.07	167.53	160.60
21	174.13	184.08	180.40	193.10	199.37	156.80	178.20	159.50	165.60	165.44	163.18	159.72
22	180.95	181.99	180.95	142.34	204.60	140.96	177.43	157.41	165.49	149.82	156.64	167.25
23	160.05	185.90	195.91	184.14	57.75	146.30	176.11	158.40	169.51	155.54	156.25	166.26
24	179.46	184.96	192.72	193.93	130.13	176.27	166.37	158.40	164.50	155.48	165.49	157.30
25	176.55	181.50	192.83	191.84	178.20	171.10	168.63	159.50	160.60	157.46	164.39	156.25
26	175.34	195.80	191.40	193.65	182.05	176.60	169.89	155.15	155.10	155.48	167.75	164.01
27	176.44	184.80	198.38	194.81	196.24	178.31	168.63	158.51	165.33	153.23	162.80	169.67
28	175.23	181.83	26.14	137.83	189.58	176.33	158.95	158.73	1666.48	154.49	165.60	167.45
29	155.26		196.95	194.75	175.45	163.35	167.25	157.68	173.08	161.75	161.92	169.45
30	159.66		195.91	200.64	163.35	170.66	161.09	156.69	171.93	155.10	162.03	168.85
31	177.70		195.91		180.84		154.38	158.88		160.93		169.89
	5232.57	5065.54	5625.98	5636.82	5802.05	5148.78	5383.82	4875.29	6384.73	4874.19	4711.18	5083.48

Table 13-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2002

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2003:-**

Date	January	February	March	April	May	June	July	August	September	October	November	December
Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2003
1	165.16	161.86	167.47	164.01	176.33	169.62	151.80	145.31	149.82	144.48	157.52	167.31
2	171.76	165.00	166.43	162.91	177.15	183.15	157.63	154.60	150.92	139.04	157.68	165.27
3	169.73	165.38	164.28	163.07	174.13	178.69	158.73	149.65	152.24	139.86	160.93	164.17
4	169.73	147.95	165.00	162.85	175.45	157.79	158.95	149.60	150.92	142.23	158.40	165.05
5	166.54	134.75	178.35	166.65	166.48	183.86	153.06	149.05	148.77	151.80	154.05	164.34
6	167.53	160.82	164.45	166.43	169.45	184.03	154.49	148.94	149.93	147.95	154.55	166.65
7	164.50	161.81	167.47	164.50	173.85	183.70	153.01	148.83	149.65	151.80	154.16	167.47
8	165.22	163.18	171.93	173.08	180.89	181.55	135.41	147.56	142.01	150.15	152.18	170.66
9	164.12	161.92	173.91	173.85	180.73	184.80	148.00	145.47	148.61	152.02	155.43	166.26
10	165.22	163.29	176.33	172.09	180.62	186.39	150.20	149.98	148.88	150.86	155.32	165.27
11	165.16	163.29	173.85	157.52	181.00	185.02	148.72	148.94	153.12	154.22	151.25	165.11
12	161.81	162.14	172.97	169.78	180.84	162.30	153.28	149.76	152.07	149.71	154.00	170.94
13	163.29	162.85	173.80	167.31	177.43	161.20	148.50	150.86	137.77	151.85	154.33	176.00
14	162.85	162.30	168.35	170.88	179.74	156.47	152.07	149.82	146.57	146.74	154.05	168.30
15	164.34	165.33	167.58	168.68	171.82	162.25	147.95	147.95	152.40	147.40	154.55	167.53
16	163.95	166.54	168.79	167.58	181.72	166.37	152.07	148.94	150.81	154.16	154.16	168.52
17	165.05	167.42	165.11	173.19	179.90	152.18	152.90	149.65	69.74	155.10	155.65	168.52
18	163.18	159.72	165.44	173.96	177.54	172.86	147.89	150.09	144.59	154.27	157.52	163.90
19	159.94	157.90	167.80	175.01	180.45	154.55	149.87	146.57	149.05	146.79	163.07	175.23
20	160.82	164.06	166.43	174.29	179.63	159.94	149.71	149.10	152.07	145.36	164.23	167.25
21	162.25	161.86	168.79	175.50	176.22	160.87	151.08	147.40	150.04	151.05	167.31	167.69
22	160.76	165.22	176.27	153.45	171.60	160.65	152.35	146.63	154.05	147.89	162.30	159.55
23	165.16	166.48	151.08	171.98	179.85	161.92	149.05	148.66	151.03	145.69	153.28	165.27
24	162.91	168.68	22.33	179.90	173.80	150.92	146.52	148.83	151.14	146.57	165.16	165.38
25	164.34	168.35	122.59	178.31	178.42	163.18	140.19	148.50	150.92	149.05	164.06	169.40
26	166.54	171.71	159.55	176.55	179.57	158.56	143.00	149.05	148.99	148.50	165.22	168.30
27	165.55	177.43	158.95	178.31	169.56	153.23	145.53	147.67	148.88	150.92	166.10	166.37
28	168.63	171.87	160.93	177.43	175.28	157.35	145.69	148.61	150.20	151.80	168.46	169.84
29	143.05		163.29	178.75	171.10	156.47	145.20	148.66	147.45	151.19	167.64	166.32
30	168.63		162.96	178.47	183.70	162.14	146.35	152.40	150.09	149.05	169.73	165.49
31	162.80		163.02		177.55		146.52	149.65		156.64		170.72
	5090.52	4569.11	4995.50	5116.29	5481.80	5012.01	4635.72	4616.73	4402.73	4624.14	4772.29	5188.08

Table 14-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2003

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2004:-**

Date	January	February	March	April	May	June	July	August	September	October	November	December
	Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2004											
1	171.71	168.63	172.86	173.91	174.18	175.28	156.36	151.96	158.84	109.50	69.68	170.99
2	171.71	169.78	172.92	173.96	166.15	155.59	161.70	151.91	156.58	155.59	161.20	171.98
3	171.82	159.66	167.42	170.55	173.08	167.80	154.05	146.63	154.05	156.47	158.73	169.40
4	171.82	166.32	180.51	159.88	170.50	175.39	153.45	139.70	154.44	158.40	156.53	167.25
5	170.61	166.54	179.79	162.85	153.01	176.38	157.30	153.23	158.73	157.30	157.85	161.20
6	151.30	170.55	174.90	161.81	172.81	167.42	149.98	161.04	159.66	158.40	155.15	165.60
7	157.74	168.46	169.89	166.32	172.81	176.55	156.80	158.67	159.50	147.40	158.45	170.88
8	166.32	168.74	171.05	171.98	168.63	179.41	156.75	154.05	155.70	156.69	155.21	162.08
9	162.25	170.88	166.32	177.15	170.66	170.00	155.10	155.54	159.55	156.69	156.80	170.55
10	162.03	176.27	170.72	176.16	168.57	123.64	145.69	155.21	154.60	154.16	159.72	172.75
11	167.36	171.10	178.42	177.26	168.79	157.63	156.20	155.37	159.94	152.40	163.29	173.96
12	171.05	170.94	182.60	183.97	169.84	163.18	153.50	150.92	162.19	158.84	165.38	170.77
13	170.50	173.96	175.12	181.50	169.84	153.34	146.68	153.28	161.86	154.44	166.43	170.55
14	167.69	168.90	174.95	183.09	170.66	121.33	153.50	150.86	163.07	151.91	160.10	165.60
15	165.60	164.34	175.28	179.30	172.81	113.41	152.07	156.53	161.86	155.54	160.82	164.34
16	168.63	171.05	177.21	177.43	170.50	147.95	148.50	146.79	159.61	157.85	162.91	169.40
17	168.41	169.51	174.24	173.03	172.97	155.48	142.50	148.55	164.12	155.37	164.01	169.78
18	167.31	170.50	173.19	179.74	173.19	147.45	146.90	152.40	168.90	154.55	153.45	166.48
19	167.36	170.72	174.24	176.44	176.16	156.80	158.40	151.80	169.84	153.50	160.82	168.63
20	169.78	160.87	175.23	172.86	172.92	158.40	158.40	155.32	166.54	155.15	160.93	166.65
21	170.66	169.73	169.67	172.81	171.10	160.60	159.00	157.68	165.16	157.63	163.07	163.40
22	168.68	169.73	169.62	180.67	171.76	160.82	158.40	157.35	164.06	154.44	159.50	166.26
23	169.95	175.26	178.69	176.00	169.89	162.19	158.89	156.69	166.21	157.30	161.04	169.95
24	172.04	171.96	182.87	173.25	174.24	160.98	156.53	156.42	168.41	156.20	150.04	170.83
25	168.30	173.03	180.67	173.08	159.66	169.89	149.82	139.70	167.80	156.64	160.05	170.94
26	166.70	174.18	180.51	176.38	177.37	167.36	151.30	156.64	156.36	164.06	160.87	172.81
27	170.66	171.82	149.71	178.69	176.11	161.81	155.21	152.13	160.05	126.28	164.06	171.60
28	170.83	173.30	171.76	176.11	174.95	159.72	156.36	154.55	158.95	169.51	162.03	170.88
29	170.83	146.46	172.09	173.08	174.02	160.98	155.21	155.48	160.10	171.93	167.58	170.99
30	172.20		171.65	172.09	175.28	157.35	143.27	150.86	157.90	134.20	167.69	173.19
31	169.95		172.92		177.54		155.32	158.89		17.82		174.40
	5211.80	4903.19	5387.02	5231.35	5310.00	4764.13	4763.14	4746.150	4834.58	4626.16	4723.39	5244.09

Table 15-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2004

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2005:-**

Date	January	February	March	April	May	June	July	August	September	October	November	December

Date	January	February	March	April	May	June	July	August	September	October	November	December
1	172	173	175	185	175	168	126	160	160	162	166	168
2	173	176	179	184	171	166	147	157	160	163	164	171
3	178	173	180	183	171	176	160	163	160	157	163	173
4	178	175	186	188	174	177	177	160	160	158	163	172
5	175	173	178	182	175	176	169	162	163	71	163	175
6	173	171	175	182	174	178	153	163	159	167	162	175
7	173	168	178	183	172	177	165	160	154	168	158	174
8	174	167	179	179	171	171	171	158	156	166	164	176
9	175	171	178	180	171	167	171	158	158	165	164	173
10	174	174	178	182	171	176	168	151	160	166	115	177
11	176	172	176	181	170	177	163	157	160	161	164	174
12	176	173	174	181	171	176	155	158	156	152	168	174
13	176	172	175	183	171	182	161	160	160	164	170	171
14	178	172	168	184	169	181	160	155	162	165	172	175
15	53	173	176	174	171	180	151	161	161	163	164	174
16	104	178	170	159	170	180	160	158	150	165	174	175
17	150	172	177	165	177	176	149	159	156	162	170	176
18	162	183	172	173	174	172	153	160	158	162	170	175
19	164	178	174	175	165	176	153	155	159	161	169	176
20	166	179	170	175	171	172	160	161	158	163	169	176
21	164	183	174	174	153	168	158	163	152	163	170	179
22	164	183	174	176	174	167	160	153	158	162	169	177
23	174	175	174	157	176	162	160	145	156	160	169	177
24	173	19	181	173	176	162	142	155	151	164	168	174
25	180	69	182	174	173	150	141	157	160	164	170	175
26	178	162	181	175	176	146	141	157	163	160	170	181
27	181	163	183	173	161	131	158	156	157	134	167	179
28	182	164	184	171	170	85	162	160	156	161	166	178
29	177		185	173	171	99	161	158	158	164	167	183
30	177		177	175	160	112	160	160	149	163	167	181
31	174		186		182		149	157		167		181
	5174	**4591**	**5499**	**5299**	**5306**	**4886**	**4864**	**4897**	**4730**	**4923**	**4955**	**5445**

Table 16-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2005

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2006:-**

Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2006											
Date	January	February	March	April	May	June	July	August	September	October	November	December
1	178	177	185	177	169	159	170	165	172	176	179	168
2	181	186	48	179	172	160	139	161	171	176	165	176
3	178	182	152	181	172	160	160	169	169	172	176	169
4	180	182	28	184	160	151	152	166	175	177	179	169
5	180	171	115	184	174	152	100	146	171	175	180	170
6	177	182	163	183	176	148	157	155	176	170	177	168
7	180	183	167	185	177	153	175	164	179	163	177	169
8	179	183	173	183	176	159	171	166	173	170	181	167
9	181	183	169	186	173	166	174	166	165	171	181	156
10	181	182	176	187	176	171	172	165	171	179	181	160
11	179	180	176	184	177	165	174	166	176	176	181	70
12	182	173	23	176	179	156	167	167	172	178	180	72
13	180	184	107	184	179	144	173	164	160	175	179	149
14	182	186	168	183	180	172	169	162	179	179	181	159
15	179	185	180	170	180	168	171	166	176	178	177	169
16	183	185	183	164	178	174	167	169	164	173	172	167
17	181	184	185	158	180	172	170	168	158	181	162	166
18	177	185	177	173	182	167	169	168	168	154	179	172
19	179	188	185	178	179	167	161	167	167	175	184	163
20	178	187	184	178	186	171	170	171	170	175	184	174
21	177	188	185	180	183	176	170	159	170	173	183	171
22	171	181	187	182	185	169	164	169	167	175	173	169
23	172	177	178	182	183	172	173	159	167	178	182	170
24	170	178	180	183	170	167	173	158	171	176	184	166
25	177	172	86	181	156	169	174	173	167	184	186	166
26	180	172	162	140	166	160	174	170	162	186	186	164
27	175	184	181	27	168	169	170	164	173	180	182	165
28	173	184	182	147	175	166	162	170	174	161	181	162
29	174		179	168	169	165	167	165	175	182	180	154
30	172		184	157	167	159	152	169	174	178	186	167
31	172		182		157		163	169		175		170
	5508	5084	4830	5124	5404	4907	5103	5116	5112	5421	5378	4957

Table 17-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2006

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2007:-**

Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2007											
Date	January	February	March	April	May	June	July	August	September	October	November	December
1	173	168	147	182	178	170	136	112	161	50	164	167
2	169	174	171	180	178	173	147	157	156	93	159	161
3	168	179	177	181	179	167	149	160	162	151	162	166
4	171	179	178	179	180	172	150	160	163	161	161	163
5	171	179	179	184	178	173	147	157	160	161	167	164
6	173	180	181	185	176	170	151	156	160	136	161	169
7	169	178	180	183	176	162	156	159	159	161	158	166
8	174	173	181	181	178	170	158	156	163	166	163	160
9	161	171	185	185	180	173	157	159	155	169	161	167
10	173	168	161	185	181	167	160	161	157	166	167	167
11	174	165	179	186	173	172	155	156	160	164	164	169
12	175	169	176	181	181	172	157	157	165	163	165	169
13	172	178	181	185	178	171	153	161	165	167	165	168
14	176	185	180	182	170	175	147	148	161	167	165	171
15	173	185	175	182	166	172	152	149	163	168	166	172
16	168	181	182	183	181	171	152	155	159	169	164	169
17	175	178	182	183	182	169	151	166	161	172	164	169
18	174	176	180	184	181	174	154	167	160	172	164	162
19	171	178	182	171	181	173	152	164	160	168	167	171
20	170	177	183	187	173	174	154	168	165	146	169	170
21	170	164	184	183	181	162	153	166	163	163	166	173
22	172	171	184	178	178	168	153	167	164	166	166	171
23	174	170	184	186	177	129	156	167	161	165	167	172
24	171	167	182	187	178	133	151	157	162	166	159	167
25	172	169	182	186	180	151	157	163	165	167	164	172
26	169	172	184	184	182	131	158	160	165	16	169	172
27	175	174	186	188	179	145	154	163	163	163	166	173
28	174	177	183	156	178	136	153	159	161	161	169	175
29	177		176	159	138	129	152	164	159	165	172	172
30	174		176	160	22	134	154	164	160	166	172	170
31	163		187		166		70	159		162		171
	5321	4885	5548	5416	5309	4838	4649	4917	4838	4730	4946	5228

Table 18-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2007

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2008:-**

Date	January	February	March	April	May	June	July	August	September	October	November	December
	Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2008											
1	173	164	163	173	176	176	165	159	162	173	173	176
2	174	174	164	176	175	172	152	169	169	170	161	176
3	175	178	138	174	173	176	170	167	175	174	174	175
4	165	177	125	173	170	175	168	176	171	172	176	176
5	175	167	173	173	172	173	165	176	174	168	175	174
6	174	175	171	171	174	175	176	171	173	168	172	176
7	172	172	174	169	175	174	171	173	168	168	176	175
8	173	177	176	173	176	175	171	171	168	168	173	173
9	176	177	176	175	176	173	166	174	162	171	176	173
10	176	180	175	169	171	174	175	174	160	161	163	175
11	179	168	176	174	176	176	176	171	163	157	176	176
12	174	178	176	174	173	166	170	168	174	50	176	175
13	175	179	176	172	166	175	174	172	173	128	166	176
14	172	173	176	170	176	176	174	176	173	168	176	174
15	176	172	174	169	173	169	176	174	173	160	174	176
16	172	164	164	174	176	167	170	170	171	153	170	176
17	178	164	170	176	176	165	171	176	171	172	173	176
18	176	162	173	123	141	169	175	175	173	162	172	173
19	175	163	170	163	117	165	176	170	173	172	173	176
20	179	159	176	174	163	171	174	158	176	169	167	167
21	180	156	174	168	162	169	176	160	175	172	173	173
22	181	164	174	172	168	170	173	177	171	171	176	169
23	178	164	172	176	141	165	175	174	174	169	168	173
24	177	164	170	176	172	163	174	170	176	168	172	166
25	176	164	176	176	173	171	174	167	173	171	176	164
26	177	163	142	176	176	170	172	165	172	171	174	165
27	179	157	172	176	161	171	172	163	174	168	174	174
28	173	163	170	176	166	168	170	171	173	171	174	174
29	175	159	168	176	175	167	173	162	174	170	174	173
30	108		163	176	170	165	168	148	172	170	173	172
31	68		167	176	172		164	164		174		173
	5261	**4877**	**5214**	**5319**	**5211**	**5121**	**5306**	**5241**	**5136**	**5059**	**5176**	**5370**

Table 19-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2008

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2009:-**

Date	January	February	March	April	May	June	July	August	September	October	November	December

Date	January	February	March	April	May	June	July	August	September	October	November	December
1	174	176	176	186	128	186	181	181	166	163	172	171
2	176	163	175	187	186	189	168	191	164	160	178	183
3	173	175	164	189	188	189	181	188	164	168	186	180
4	176	174	175	176	189	189	177	186	165	162	185	177
5	176	176	174	189	191	184	183	191	157	164	180	183
6	176	176	176	191	190	189	179	174	155	165	171	186
7	171	172	172	191	191	175	178	166	158	164	173	180
8	176	176	174	191	191	190	182	171	157	155	180	165
9	32	72	176	191	191	190	184	139	158	156	180	177
10	145	65	176	175	189	189	167	174	150	165	176	177
11	170	158	176	116	191	186	182	176	167	163	175	180
12	169	176	176	83	188	186	185	170	163	162	173	181
13	174	176	176	184	185	186	178	175	171	155	176	176
14	174	174	133	186	189	191	146	176	146	151	177	178
15	176	174	155	186	189	190	141	171	173	152	166	188
16	174	172	173	188	191	187	165	170	173	161	167	186
17	176	173	150	191	190	171	175	171	175	157	173	172
18	176	176	152	191	184	181	183	167	131	155	169	179
19	176	174	175	190	187	167	177	175	168	160	174	170
20	175	173	175	185	181	191	155	172	171	154	173	172
21	176	176	175	187	189	186	175	179	176	169	173	176
22	174	176	172	183	143	190	174	172	173	176	178	183
23	176	176	191	186	187	181	182	173	185	172	172	183
24	176	170	191	184	191	191	179	166	186	169	175	187
25	176	176	188	186	189	177	173	172	163	173	179	187
26	176	169	185	185	191	191	181	171	174	173	180	179
27	176	176	186	189	191	191	185	168	175	163	184	173
28	176	173	186	186	90	187	177	171	168	170	182	173
29	173		188	154	114	191	169	173	167	166	173	176
30	168		190	87	184	190	188	173	162	167	175	180
31	174		191		188		188	162		161		183
	5236.00	4643.00	5422.00	5293.00	5566.00	5581.00	5438.00	5364.00	4961.00	5051.00	5275.00	5541.00

Table 20-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2009

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2010:-**

Date	Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2010
	January	February	March	April	May	June	July	August	September	October	November	December
1	168	176	191	191	209	208	179	187	170	191	191	196
2	170	178	191	191	213	214	186	191	176	189	189	184
3	178	178	191	191	211	213	186	174	180	183	190	196
4	178	178	187	190	213	206	189	191	190	191	188	192
5	178	176	190	188	218	188	192	175	191	181	186	197
6	176	169	191	171	211	197	193	180	187	184	183	198
7	178	177	191	186	195	205	195	173	191	190	183	193
8	178	175	191	189	208	205	198	169	188	191	185	190
9	178	172	191	189	209	211	190	174	191	191	183	195
10	178	175	191	189	212	203	198	178	191	189	174	193
11	178	178	191	189	212	207	194	181	191	191	177	191
12	171	178	191	188	200	207	162	185	191	177	180	177
13	171	178	191	191	205	201	191	182	190	178	180	187
14	177	178	191	191	216	201	190	191	191	177	180	187
15	178	178	191	187	196	213	191	186	191	176	175	188
16	178	178	191	178	213	207	191	180	191	178	182	192
17	174	169	185	190	214	176	191	184	191	185	180	193
18	178	178	190	191	195	194	191	189	184	190	183	191
19	166	178	190	191	204	209	191	181	178	191	177	189
20	165	175	191	191	212	212	191	179	184	194	188	193
21	165	178	190	191	213	212	187	178	187	195	191	196
22	176	178	190	190	209	202	167	188	172	190	189	191
23	174	178	191	191	161	197	182	191	176	190	185	197
24	161	178	191	189	192	198	186	177	183	190	180	198
25	169	174	188	191	200	211	184	178	180	192	190	198
26	168	178	191	189	210	200	173	175	185	194	191	198
27	169	178	189	190	211	205	184	174	191	191	190	198
28	174	173	189	205	218	190	191	174	186	191	187	197
29	175		191	218	216	189	190	169	190	191	191	193
30	176		191	218	217	186	185	171	188	193	195	198
31	171		191		206		183	169		190		197
	5374	4937	5899	5734	6419	6067	5801	5574	5575	5824	5543	5983

Table 21-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2010

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2011:-**

Date	January	February	March	April	May	June	July	August	September	October	November	December
				Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2011							
1	191	212.26	210.25	209.78	211.69	206.72	188.01	214.52	216.50	214.64	209	214
2	191	214.19	211.17	211.64	211.77	206.23	201.96	205.82	210.86	215.38	211	211
3	192	211.97	209.60	209.29	210.04	181.79	208.14	211.81	212.98	211.66	212	211
4	192	209.16	210.59	211.17	205.00	200.63	196.66	213.16	214.38	216.95	212	194
5	189	211.27	214.37	211.41	204.79	184.98	203.05	212.00	214.53	215.61	195	210
6	196	208.64	209.05	214.96	208.42	206.21	205.36	208.78	215.74	212.10	210	214
7	198	212.54	210.97	214.71	210.16	202.67	206.43	212.68	215.21	216.16	210	211
8	190	212.03	212.47	208.83	211.02	212.65	203.46	210.84	215.46	216.04	209	212
9	196	211.92	209.89	207.33	208.20	199.58	204.58	213.47	215.93	217.51	211	208
10	195	209.42	201.38	206.98	198.86	188.73	205.96	213.32	213.24	214.17	212	209
11	194	214.23	201.10	196.87	207.33	188.87	205.89	213.54	217.10	215.74	211	210
12	195	214.04	215.31	206.82	207.52	149.13	194.30	213.27	214.42	174.42	212	213
13	198	214.83	213.21	210.64	207.22	189.87	194.79	213.66	215.18	174.93	212	212
14	196	215.03	208.51	211.55	208.36	189.26	206.47	215.15	215.40	214.49	209	209
15	196	204.48	202.89	208.35	204.96	171.71	198.08	213.34	203.56	208.05	213	212
16	199	211.36	208.53	213.56	209.72	160.74	174.86	214.06	215.64	211.12	209	205
17	52	204.56	207.93	211.76	201.36	141.72	169.15	210.17	216.38	209.87	212	216
18	138	224.10	199.18	209.71	187.57	180.11	182.50	215.19	212.32	206.62	212	211
19	195	210.50	216.69	210.55	208.22	181.25	176.00	215.08	214.59	203.14	211	215
20	198	212.11	212.62	211.19	206.73	170.75	187.82	215.09	215.66	210.33	209	211
21	195	212.29	205.88	211.20	206.39	184.05	201.89	215.62	215.45	231.52	209	212
22	197	207.39	212.48	213.65	164.00	182.35	206.20	211.65	214.20	212.38	207	213
23	199	207.00	209.65	213.09	207.04	191.52	209.71	215.59	212.87	213.46	211	209
24	198	201.98	207.93	159.98	203.43	196.27	190.53	211.50	216.16	212.21	213	213
25	199	211.00	212.91	213.63	205.33	171.34	204.92	218.06	215.08	211.29	211	211
26	199	211.33	210.85	213.82	207.76	171.60	210.74	213.55	214.75	206.79	209	210
27	199	211.00	212.15	209.83	201.75	177.49	210.26	207.29	214.63	210.21	209	205
28	199	210.00	207.28	213.78	209.97	207.40	208.32	216.15	215.37	174.93	208	207
29	199		210.55	199.69	208.64	203.09	205.61	215.97	215.59	205.59	212	209
30	199		210.42	209.65	208.07	206.27	211.39	214.68	214.81	206.39	209	211
31	199		212.68		208.79		212.01	215.88		208.10		210
	5873	5910.63	6498.49	6255.42	6360.11	5604.98	6185.05	6610.89	6433.99	6471.80	6299	6518

Table 22-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2011

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2012:-**

Date	January	February	March	April	May	June	July	August	September	October	November	December
	Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2012											
1	208	216	205	218	218	195.48	192.54	196.49	201.76	191.52	199.56	207.86
2	209	214	218	215	218	193.69	197.96	196.65	204.80	191.52	198.53	209.26
3	207	213	218	214	217	188.13	197.45	189.75	203.84	191.52	193.97	204.51
4	195	214	218	218	218	191.45	181.27	193.28	203.80	192.88	193.29	203.86
5	195	215	218	218	215	194.23	176.95	197.62	202.91	200.64	193.29	200.18
6	204	216	217	218	217	198.41	161.82	187.72	198.56	193.23	191.52	199.54
7	206	215	209	218	218	197.22	149.39	199.96	198.44	196.36	190.78	196.96
8	211	218	217	217	217	192.30	164.49	201.48	197.15	195.39	201.15	202.87
9	210	217	217	218	218	198.69	174.18	200.96	203.40	194.94	197.33	207.79
10	194	218	217	217	217	196.60	183.46	202.29	201.68	191.52	192.94	205.29
11	209	218	218	217	218	198.04	181.27	202.33	201.82	193.97	194.03	209.79
12	209	216	214	218	218	198.45	183.05	199.22	199.93	197.22	196.71	203.95
13	213	217	218	217	218	195.63	178.03	197.28	201.71	199.95	207.48	203.27
14	212	217	218	209	218	196.14	185.81	197.28	200.56	191.52	197.62	205.78
15	204	226	218	217	218	198.13	192.20	197.64	193.95	184.11	194.26	203.33
16	204	217	218	217	218	197.75	193.72	197.13	201.50	197.67	199.78	202.33
17	210	218	218	218	214	198.02	191.86	195.69	201.19	197.44	192.66	194.99
18	209	218	218	218	218	203.51	202.12	200.72	200.92	199.89	202.92	186.83
19	211	218	218	218	149	203.31	200.61	201.47	206.14	200.81	198.47	190.52
20	214	217	218	218	218	201.31	199.84	197.49	211.11	196.08	204.25	178.98
21	214	211	214	218	209	198.52	201.64	199.38	175.27	201.03	204.36	178.15
22	209	218	218	215	218	192.01	202.26	200.18	183.96	203.43	203.35	196.43
23	210	218	218	218	217	201.13	203.27	199.59	211.60	194.02	202.98	193.86
24	241	218	217	218	218	192.93	201.64	205.10	201.25	199.50	195.85	196.68
25	215	218	213	218	218	190.04	204.22	187.88	197.97	198.98	202.96	196.99
26	213	218	218	217	212	196.77	215.97	204.35	197.20	190.83	207.16	192.62
27	214	199	218	217	214	194.33	186.90	203.68	200.59	202.29	201.83	189.39
28	212	218	218	218	218	197.35	200.72	198.91	199.93	201.83	204.36	193.39
29	218	208	212	218	218	194.16	193.73	195.10		198.81	207.9	204.38
30	215		218	218	216	199.65	192.13	202.89		200.86	208.67	204.18
31	213		218		217		193.91	206.01		196.70		203.15
	6508	6264	6712.00	6513	6655.00	5893.38	5884.41	6155.52	5602.94	6086.46	5979.96	6167.11

Table 23-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2012

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2013:-**

Date	January	February	March	April	May	June	July	August	September	October	November	December
	Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2013											
1	202.94	182.83	207.97	187.43	202.32	128.28	199.52	199.00	200.19	200.50	204.00	209.00
2	191.39	199.40	205.31	194.02	197.09	196.46	189.65	203.00	202.54	198.00	213.00	207.00
3	198.13	199.64	202.18	193.01	202.74	202.24	182.87	196.00	197.37	201.50	195.00	206.00
4	191.93	197.88	198.52	184.56	199.66	200.55	184.50	201.00	203.77	203.00	205.00	204.00
5	192.79	198.11	209.58	159.89	201.84	199.54	188.03	204.00	204.68	97.00	194.00	202.00
6	188.14	202.90	211.23	180.63	201.02	201.14	182.07	195.00	204.14	201.00	189.00	205.00
7	180.35	202.99	206.48	180.39	192.18	197.12	188.69	200.00	198.00	199.00	203.00	202.00
8	187.88	205.16	191.25	176.53	176.69	201.24	195.52	201.00	202.00	200.00	193.00	204.00
9	191.67	202.41	205.65	183.76	199.64	197.23	194.89	200.00	199.00	203.00	202.00	207.00
10	190.62	205.70	204.94	191.08	201.84	200.45	196.08	197.00	201.00	197.00	204.00	143.00
11	190.08	202.74	205.16	181.01	200.06	201.74	91.26	199.00	197.00	200.00	204.00	169.00
12	192.20	205.33	203.25	179.73	201.86	202.50	183.52	200.00	203.00	201.00	201.00	209.00
13	190.92	206.44	207.57	189.56	200.70	188.68	192.98	198.00	200.00	198.00	207.00	197.00
14	187.01	207.58	205.71	182.63	201.88	195.34	191.75	204.92	204.58	199.00	207.00	193.00
15	191.94	200.52	204.24	189.19	201.57	204.78	194.46	206.54	205.40	200.00	195.00	211.00
16	190.82	211.59	200.30	181.51	201.40	202.23	193.22	205.82	206.90	203.00	208.00	212.00
17	184.43	206.27	198.93	184.80	205.99	204.69	191.08	206.85	206.53	200.00	207.00	212.00
18	187.94	210.50	184.86	189.56	197.62	204.38	201.64	206.95	207.69	203.00	195.00	213.00
19	185.22	209.33	198.81	180.39	201.72	201.65	200.25	206.20	204.33	204.00	207.00	204.00
20	186.18	209.11	197.89	198.72	200.63	202.23	199.12	197.38	206.21	201.00	211.00	201.00
21	188.24	208.30	201.63	192.46	203.35	196.91	169.05	206.90	201.93	204.00	204.00	211.00
22	185.12	207.39	198.41	195.57	204.39	199.32	177.25	205.98	205.36	203.00	209.00	214.00
23	187.87	174.48	197.15	197.37	201.92	201.39	188.81	203.69	206.32	204.00	212.00	209.00
24	188.84	126.02	190.62	198.36	202.75	199.05	204.99	195.73	195.93	204.00	213.00	212.00
25	191.07	203.55	189.12	197.46	201.51	196.74	201.34	199.34	205.93	203.00	211.00	213.00
26	198.87	198.13	187.49	193.23	162.90	189.50	201.02	200.25	205.07	205.00	188.00	213.00
27	194.51	205.57	192.92	194.18	200.87	197.58	200.51	203.57	205.11	204.00	194.00	213.00
28	197.79	208.73	182.77	191.71	175.12	183.80	204.34	204.01	198.37	205.00	205.00	212.00
29	199.90		189.96	198.59	190.61	195.32		204.41	202.43	205.00	208.00	212.00
30	196.37		182.78	200.12	181.61	199.44		204.27	203.02	205.00	208.00	214.00
31	192.90		196.47		198.60			204.33		204.00		213.00
	5924.06	5598.60	6159.15	5647.45	6112.08	5891.52	5288.41	6260.14	6083.80	6155.00	6096.00	6346.00

Table 24-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2013

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2014:-**

Date	January	February	March	April	May	June	July	August	September	October	November	December
	Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2014											
1	191.29	212.53	220.16	219.49	214.77	207.97	200.50	209.15	216.39	217.15	210.62	207.42
2	202.61	218.75	221.96	218.88	215.41	204.04	84.17	213.20	216.90	217.79	210.24	212.86
3	210.04	214.97	218.27	221.64	212.47	179.58	199.86	212.79	218.21	216.24	210.36	209.28
4	212.08	208.14	217.37	215.50	216.30	208.05	203.94	212.69	216.82	202.70	207.68	207.74
5	213.49	197.57	217.47	216.20	215.56	207.27	203.78	206.86	217.74	223.44	209.98	210.17
6	211.76	208.65	217.81	212.86	213.70	206.69	201.67	211.02	217.62	225.08	208.76	211.90
7	206.92	200.00	221.10	214.82	215.00	207.15	202.63	213.49	217.77	227.46	212.80	212.80
8	212.01	219.07	216.21	210.71	200.57	206.10	205.65	213.36	217.30	223.65	211.45	208.96
9	206.59	219.72	217.67	211.06	214.23	206.63	185.50	212.49	148.76	227.08	209.08	59.13
10	200.70	217.38	214.80	213.08	205.61	205.39	204.86	212.15	189.31	220.45	213.05	207.68
11	205.03	219.91	170.62	213.30	210.66	194.12	206.49	202.87	219.18	223.38	208.70	205.44
12	218.92	212.91	219.44	212.05	209.33	182.29	210.41	211.26	217.60	225.89	212.60	206.52
13	218.52	219.00	219.69	211.89	209.44	207.42	202.68	214.50	217.66	226.30	211.20	210.30
14	218.65	218.97	218.29	211.45	214.93	208.31	207.80	214.39	216.36	141.98	208.70	212.60
15	218.05	219.00	218.16	210.53	214.58	208.11	184.62	207.95	214.14	216.85	209.15	213.95
16	205.43	218.14	219.19	206.11	215.54	206.92	199.97	211.70	217.91	222.36	203.52	208.00
17	216.50	218.61	220.41	202.96	169.09	203.84	200.80	215.25	218.13	224.46	201.53	202.30
18	216.10	212.90	214.57	210.53	201.99	203.74	209.08	202.71	217.82	225.14	211.32	209.21
19	215.47	184.42	212.11	210.86	177.73	206.84	205.28	216.27	218.27	221.00	204.80	211.64
20	219.54	219.04	220.20	210.24	181.94	188.14	199.77	209.15	217.68	223.78	208.00	205.37
21	218.40	217.77	222.40	205.12	208.47	167.35	208.14	209.33	218.05	222.29	210.11	212.48
22	218.70	221.59	219.02	212.40	202.27	162.83	196.80	188.54	218.38	220.66	211.26	211.26
23	217.08	212.18	218.25	205.77	217.86	157.69	129.22	211.59	218.31	223.58	208.89	207.15
24	219.40	219.31	218.10	212.41	217.91	201.31	200.00	205.03	218.09	223.31	207.93	211.39
25	219.60	219.49	216.68	209.93	205.33	194.80	207.91	213.33	210.09	223.17	209.28	210.72
26	219.78	215.81	223.48	205.04	218.40	197.10	211.98	118.90	218.30	223.04	206.40	210.42
27	212.78	218.41	223.02	199.00	217.06	187.41	209.74	215.88	214.68	223.65	210.24	210.94
28	214.02	220.01	220.09	206.53	216.97	180.06	212.17	215.94	213.11	224.04	212.54	212.39
29	217.69		222.09	206.68	217.77	188.75	209.60	216.43	219.37	226.74	211.45	209.01
30	219.88		221.40	210.44	205.18	200.00	197.17	215.62	217.54	223.24	211.26	211.95
31	219.40		214.18		208.16	0.00	212.05	216.70	0.00	223.38		211.57
	6616.43	**6004.25**	**6734.21**	**6327.48**	**6464.23**	**5885.90**	**6114.24**	**6450.54**	**6417.49**	**6809.28**	**6282.90**	**6352.55**

Table 25-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2014

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2015:-**

Date	Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2015
	January	February	March	April	May	June	July	August	September	October	November	December
1	211.62	212.84	211.29	214.57	213.46	226.20	227.00	223.40	226.29	224.76	230.66	232.74
2	210.91	213.93	219.77	213.46	213.91	230.90	223.30	227.50	226.44	231.16	230.68	232.56
3	210.81	213.76	218.17	213.91	213.76	230.20	217.60	223.90	225.64	224.89	230.97	234.04
4	212.13	213.10	194.35	211.83	213.66	229.40	219.30	225.10	226.43	228.37	228.83	232.69
5	214.00	213.90	220.17	215.64	207.48	229.80	228.20	225.60	223.39	225.37	229.46	232.70
6	206.50	213.18	218.64	207.52	204.58	232.70	228.00	222.10	226.58	229.25	231.35	229.08
7	207.53	216.21	219.79	206.48	215.69	231.90	228.50	220.20	226.58	229.87	231.03	232.25
8	206.22	214.41	221.00	211.06	210.70	228.00	229.30	221.30	227.50	228.06	232.51	233.10
9	209.81	213.83	220.92	211.44	181.86	232.00	216.60	226.00	226.83	233.09	231.33	231.26
10	210.43	215.68	216.91	187.84	210.03	231.30	230.20	222.50	143.37	229.64	233.95	231.42
11	207.84	217.97	213.79	212.38	214.40	229.90	227.10	223.70	227.01	231.55	232.37	231.41
12	206.52	216.28	213.43	209.69	213.18	222.40	226.30	222.80	228.50	230.93	232.72	232.78
13	208.67	206.48	218.72	209.48	210.14	221.50	227.30	223.10	227.38	201.27	229.91	232.91
14	204.95	217.20	215.23	211.34	214.24	217.70	227.50	216.80	228.26	229.51	231.25	230.17
15	209.89	217.99	207.36	210.44	215.42	219.10	228.40	223.80	228.48	230.95	233.98	233.33
16	207.72	218.01	214.66	210.13	220.35	221.70	222.30	223.10	226.40	226.62	234.92	170.19
17	212.67	218.72	213.58	208.97	212.78	220.40	228.80	224.00	225.29	229.65	234.02	231.53
18	210.05	218.56	211.04	211.21	214.47	220.50	225.10	221.20	226.01	230.99	234.78	231.85
19	212.65	217.50	211.40	157.72	215.72	219.90	229.10	213.60	228.90	228.55	236.06	231.65
20	208.91	109.89	205.39	214.32	216.28	202.50	225.80	223.70	225.86	230.55	232.97	232.55
21	211.43	220.70	212.26	213.30	212.00	157.60	227.40	218.50	228.61	230.85	231.19	231.98
22	213.59	220.02	205.79	213.91	217.95	215.52	223.50	224.40	227.42	230.41	221.43	230.06
23	211.26	218.78	213.93	210.87	212.80	208.30	226.40	226.40	228.32	231.10	234.06	229.73
24	210.80	221.03	212.38	212.60	215.68	198.80	226.00	226.40	229.06	230.90	231.88	231.10
25	209.52	219.49	212.57	214.84	213.22	172.90	224.40	227.10	235.52	230.30	227.85	231.24
26	209.83	221.56	213.15	214.95	216.61	198.30	223.90	226.40	228.73	232.12	229.70	227.73
27	207.24	217.62	207.48	213.00	216.68	201.30	226.90	227.00	231.12	232.15	232.37	225.72
28	208.78	221.37	191.36	201.71	217.61	190.50	225.30	225.70	228.33	232.19	232.23	227.98
29	212.62		209.24	212.40	214.15	211.30	228.70	226.30	221.36	230.85	233.23	226.91
30	207.66		201.05	213.31	214.19	220.40	225.20	228.20	229.45	231.36	222.14	226.51
31	212.96		211.26		198.77		225.70	226.10		223.54		224.53
	6505.52	5960.01	6576.08	6270.32	6581.77	6472.92	6999.10	6935.90	6739.06	7090.80	6939.83	7093.70

Table 26-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2015

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2016:-**

Date	January	February	March	April	May	June	July	August	September	October	November	December
	Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2016											
1	224.75	226.56	229.85	224.71	230.89	229.34	203.41	208.75	222.11	241.83	226.25	225.29
2	225.52	228.68	228.55	223.72	220.08	227.91	213.10	206.22	224.68	223.51	226.48	227.16
3	225.97	227.39	225.42	224.04	222.19	230.44	227.64	204.60	223.59	223.04	225.83	224.83
4	225.37	227.70	225.20	224.94	228.62	230.28	226.82	206.70	222.71	223.45	224.52	227.79
5	225.34	228.48	228.47	224.37	230.93	233.73	228.11	182.45	224.95	224.76	225.28	223.88
6	224.66	227.76	230.03	224.01	231.66	227.96	228.98	182.78	224.95	223.22	225.60	227.53
7	223.44	228.28	227.76	218.61	230.06	228.06	228.91	194.96	206.98	217.85	223.57	225.15
8	224.35	228.52	228.05	225.91	232.76	232.85	229.26	199.01	207.55	223.06	224.83	225.92
9	224.60	228.94	229.20	227.17	231.27	230.30	231.01	214.95	209.06	222.88	225.48	224.44
10	222.02	228.69	228.54	227.08	229.33	221.08	210.64	215.58	220.23	214.40	224.93	225.59
11	221.99	229.04	229.79	227.90	231.60	229.28	223.37	214.39	211.92	220.25	224.87	223.32
12	223.14	227.95	228.80	226.79	228.76	231.87	218.29	218.16	224.59	198.93	225.21	224.13
13	223.99	228.47	229.94	227.48	226.60	231.18	189.52	214.14	225.43	193.09	224.82	222.91
14	224.49	228.17	225.23	227.98	230.89	226.64	200.11	213.93	216.10	198.77	224.75	220.52
15	225.37	227.61	227.43	222.70	229.49	229.60	189.69	219.16	222.69	225.87	221.76	221.41
16	223.57	229.86	227.82	149.12	229.54	221.25	203.28	218.63	221.67	225.64	224.75	220.62
17	226.01	227.95	227.87	202.93	232.55	228.92	199.03	219.30	217.34	226.42	224.78	215.63
18	225.90	228.04	226.95	230.51	231.20	230.54	124.51	198.20	223.57	225.05	225.09	222.21
19	227.24	229.53	225.12	232.14	231.92	231.84	180.40	228.70	216.53	225.93	225.44	223.47
20	227.97	228.19	218.62	232.54	228.20	230.08	198.04	228.03	220.66	225.81	224.85	223.53
21	226.52	228.23	226.73	231.87	232.15	226.94	219.81	228.18	203.09	229.22	224.60	224.36
22	227.69	229.82	225.23	231.56	231.60	229.41	223.29	225.82	223.26	219.31	224.94	225.57
23	227.44	228.13	227.80	232.27	228.90	228.13	215.65	228.03	221.69	225.21	222.96	226.18
24	227.12	229.63	227.06	231.30	231.88	228.38	216.92	225.89	222.04	226.31	225.34	222.56
25	229.02	229.27	225.41	231.98	231.39	231.37	215.71	225.58	198.64	226.05	225.77	217.98
26	228.40	229.51	226.74	230.79	231.79	226.74	216.61	225.38	223.78	225.63	225.14	219.75
27	227.34	230.37	226.58	229.17	229.74	226.62	215.64	225.36	222.87	226.47	224.92	220.29
28	228.12	230.33	225.13	230.81	231.99	205.85	204.55	225.85	223.39	226.25	225.93	222.93
29	226.82	230.29	225.96	230.76	221.70	179.60	172.66	224.05	222.10	225.93	226.76	224.76
30	225.02		224.94	230.38	230.69	203.49	159.71	223.03	223.06	226.61	226.08	225.56
31	227.81		225.47		229.21		199.72	222.30		225.49		224.60
	6996.99	6631.39	7035.69	6735.54	7119.58	6769.68	6414.39	6668.11	6571.23	6886.24	6751.53	6929.87

Table 27-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2016

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2017:-**

Date	Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2017
	January	February	March	April	May	June	July	August	September	October	November	December
1	229.74	223.25	226.72	221.82	204.48	203.34	170.95	180.29	173.47	177.46	164.91	174.62
2	224.77	227.11	227.72	221.97	200.79	208.02	178.57	182.83	172.23	179.20	161.20	175.91
3	226.63	225.55	225.56	218.59	204.64	209.01	175.98	184.09	174.90	178.59	163.09	178.20
4	224.75	225.56	228.08	220.91	201.05	207.41	175.01	172.37	172.38	177.63	171.49	177.85
5	197.56	225.22	228.29	221.03	203.16	200.55	170.98	173.12	174.30	177.13	158.72	174.16
6	190.32	225.78	225.12	222.82	197.52	190.03	171.33	173.87	171.99	177.46	165.33	178.37
7	218.23	226.65	217.18	221.73	202.61	143.92	174.36	171.83	173.51	177.78	163.69	172.67
8	222.17	227.48	227.36	221.31	199.57	176.87	185.43	172.51	172.96	179.21	164.24	183.14
9	221.08	223.18	212.97	222.90	199.24	179.85	187.50	174.56	173.90	179.77	92.14	178.41
10	210.47	226.53	226.98	223.12	202.37	182.96	194.65	173.19	174.17	181.60	182.27	178.96
11	224.62	225.83	224.11	220.64	204.67	181.34	193.93	175.40	173.88	177.75	187.18	186.60
12	226.98	226.85	226.27	222.42	195.37	180.74	194.66	174.98	173.96	178.90	181.37	191.70
13	226.28	227.15	225.42	217.81	194.37	180.11	187.01	174.73	171.66	182.15	181.22	177.19
14	226.51	226.99	226.00	221.98	191.83	181.14	186.07	174.10	174.56	184.39	181.57	191.62
15	227.06	227.39	224.96	221.66	193.25	181.23	182.63	173.02	177.61	181.45	180.74	191.14
16	225.58	229.01	222.14	220.42	190.54	176.13	187.56	173.25	179.78	179.27	181.23	194.20
17	225.78	226.68	223.21	220.03	191.24	181.98	185.78	173.69	179.99	182.81	180.94	188.08
18	226.77	229.08	224.34	220.04	191.22	180.37	176.52	172.25	179.25	181.09	166.51	196.15
19	225.75	228.31	225.19	220.61	189.01	181.55	166.65	172.37	175.69	176.92	167.01	199.95
20	226.20	227.95	225.02	220.78	190.37	172.34	170.92	172.76	178.85	181.25	168.63	188.95
21	226.68	228.01	223.28	218.01	188.31	170.96	181.41	172.66	178.46	179.37	167.89	191.74
22	226.38	228.38	225.74	217.92	189.01	169.24	181.71	175.02	178.03	178.93	169.30	185.84
23	227.31	226.38	225.13	217.03	189.28	169.94	178.82	174.84	178.80	174.95	176.35	186.08
24	225.83	228.52	224.90	216.12	209.43	171.98	185.27	173.71	179.87	180.77	181.08	184.49
25	226.16	221.54	225.65	212.38	214.27	171.70	184.70	173.66	176.39	182.54	182.97	189.06
26	226.31	226.41	225.27	212.97	212.62	173.83	188.74	169.86	178.99	187.23	181.95	189.19
27	225.36	225.40	222.97	208.10	210.76	172.67	186.05	175.30	174.08	187.44	178.75	184.68
28	226.57	225.93	225.52	216.35	214.10	149.10	184.09	171.06	178.43	182.00	172.44	172.38
29	228.34		225.52	170.78	215.10	157.26	183.93	174.15	179.19	183.00	178.19	173.87
30	219.97		224.18	208.05	204.09	168.54	185.00	174.86	177.76	184.00	174.06	173.58
31	227.56		219.18		206.55		187.01	175.88		140.00	0.00	182.85
	6913.72	6342.12	6959.98	6520.30	6200.82	5374.11	5643.22	5406.21	5279.04	5552.04	5126.46	5691.63

Table 28-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2017

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2018:-**

Date	Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2018
	January	February	March	April	May	June	July	August	September	October	November	December
1	184.48	172.17	180.76	181.81	182.78	175.61	181.53	183.42	168.77	168.39	181.49	177.01
2	178.39	190.57	178.37	181.57	184.80	178.71	182.30	173.97	170.71	173.87	181.92	176.47
3	179.37	180.54	179.63	179.74	183.02	175.98	168.76	173.46	171.14	179.67	182.53	177.67
4	176.46	183.55	179.80	183.41	183.03	177.39	157.57	173.56	169.75	182.20	171.31	181.13
5	181.49	193.52	194.99	188.01	185.16	176.99	163.91	173.08	155.91	187.13	178.21	180.23
6	186.34	181.71	177.86	198.85	176.41	175.72	153.80	170.62	170.04	187.47	178.76	185.98
7	190.57	186.76	178.23	202.89	186.55	168.79	133.75	174.87	170.59	187.90	178.10	180.63
8	177.23	183.84	178.54	199.67	185.29	175.65	158.55	172.63	165.28	178.45	178.14	182.79
9	181.96	191.15	178.72	189.12	178.23	173.63	163.39	173.85	170.03	172.20	178.94	183.23
10	177.60	170.26	181.98	195.41	178.71	172.87	169.67	170.99	166.45	177.20	172.18	168.25
11	178.51	174.27	187.66	198.20	183.35	146.05	186.05	173.36	169.62	171.42	184.47	171.71
12	181.64	189.11	185.57	188.51	184.20	178.26	173.52	171.49	169.17	176.63	183.66	164.47
13	186.46	178.63	178.72	186.94	161.63	176.18	176.89	166.35	170.88	174.57	188.65	166.65
14	182.72	172.89	204.66	201.55	180.93	167.47	176.92	170.68	171.44	174.76	187.33	174.76
15	178.94	173.71	193.10	205.10	189.83	176.01	135.40	172.31	172.07	175.97	167.71	183.96
16	180.46	190.99	180.49	205.21	170.05	179.10	191.58	171.86	170.70	182.07	183.86	197.71
17	181.77	172.66	175.56	204.93	170.83	179.70	189.98	170.20	169.99	171.37	173.78	194.20
18	187.11	174.65	184.89	196.45	171.86	179.70	188.61	159.35	170.41	174.32	177.72	193.20
19	183.82	174.94	189.42	197.64	175.05	161.58	165.96	169.25	169.20	182.20	177.59	192.23
20	189.96	125.00	174.32	200.30	173.78	176.45	172.44	170.67	171.20	181.58	169.76	194.88
21	176.54	187.36	154.23	203.07	173.40	178.70	181.05	173.78	171.48	175.26	182.30	185.74
22	180.35	179.82	170.98	202.21	172.63	174.30	184.04	170.62	169.35	185.15	180.96	176.72
23	176.03	189.96	171.98	191.94	170.44	179.75	187.97	168.41	171.21	162.02	172.75	171.30
24	175.56	186.94	172.86	185.92	172.70	180.22	187.76	167.76	170.96	181.04	177.65	191.14
25	180.49	183.04	187.08	185.45	171.21	158.86	183.33	170.10	170.75	191.56	174.36	193.49
26	175.05	187.17	185.35	185.90	176.41	181.23	32.36	170.20	170.24	188.52	178.81	180.74
27	175.80	186.58	193.00	185.90	172.32	181.10	179.39	168.62	168.57	194.04	183.08	177.78
28	182.72	181.62	199.91	185.90	176.92	183.16	188.06	170.10	166.91	192.70	178.99	179.24
29	188.01		186.80	185.42	178.85	183.95	191.60	169.59	168.26	176.54	181.80	194.71
30	187.58		184.23	183.32	160.89	183.04	183.38	168.95	169.72	173.26	181.56	165.05
31	161.72		181.49		173.02		182.60	171.03		182.18		193.37
	5605.13	5043.41	5651.18	5780.34	5484.28	5256.15	5272.12	5305.13	5080.80	5561.64	5368.37	5636.44

Table 29-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2018

- **Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2019:-**

Daily water withdrawn by 160 MLD Salaulimm water Treatment Plant for the year 2019											
Date	January	February	March	April	May	June	July	August	September	October	November	December
1	189.60	186.26	195.09	192.90	183.98	210.77	180.55	187.76	183.14			
2	193.13	190.02	195.71	199.49	180.08	206.39	176.03	184.72	185.14			
3	191.78	190.89	193.10	200.16	181.97	197.42	180.80	186.11	187.05			
4	196.12	185.40	193.78	192.41	192.85	196.27	179.71	183.79	180.96			
5	192.55	189.00	194.13	187.32	198.58	191.54	173.94	186.30	161.30			
6	191.06	181.64	195.39	189.82	182.00	187.64	160.30	187.82	186.70			
7	177.14	188.90	193.47	187.03	197.93	200.99	169.52	187.21	181.38			
8	192.99	194.25	194.96	187.03	186.27	201.34	178.25	164.58	182.54			
9	191.88	195.08	193.80	187.09	183.60	162.47	182.96	154.42	173.09			
10	187.45	194.84	192.72	183.69	190.63	201.63	179.35	184.67	185.28			
11	189.80	187.00	197.39	188.75	177.53	161.16	200.25	184.55	192.12			
12	196.13	152.71	194.25	187.81	188.08	141.09	204.39	187.83	183.03			
13	192.58	183.84	179.17	186.74	188.94	169.18	187.16	190.18	176.77			
14	196.50	185.53	180.69	186.95	188.84	190.99	183.75	187.61	183.77			
15	194.98	189.91	178.95	194.05	176.98	178.93	163.66	186.06	196.57			
16	199.02	190.94	184.24	190.30	184.29	185.50	181.61	184.73	185.50			
17	201.24	191.50	196.32	189.38	187.83	187.77	179.93	185.53	182.55			
18	199.44	166.13	199.80	189.22	189.58	157.82	177.56	186.65	187.71			
19	194.84	195.47	131.07	188.78	189.67	184.67	174.94	185.80	178.07			
20	187.23	195.35	190.68	191.42	192.16	177.79	177.07	193.77	183.67			
21	190.31	194.04	187.47	191.61	193.69	179.40	151.82	192.00	182.39			
22	191.26	199.16	186.09	192.52	186.69	180.29	176.69	189.41	176.61			
23	187.50	200.78	188.80	190.85	190.44	176.60	176.52	183.40	175.02			
24	189.01	197.60	191.37	187.95	189.55	176.76	176.61	162.92	177.01			
25	191.22	194.24	189.53	188.72	193.59	187.81	174.39	180.71	177.77			
26	190.86	190.57	188.95	190.93	189.54	191.07	176.88	184.60	172.09			
27	188.15	190.79	184.29	185.64	157.18	173.87	176.99	184.82	187.49			
28	182.52	192.82	183.83	185.20	193.49	177.76	185.18	189.03	183.28			
29	45.96		190.92	185.26	187.26	176.13	178.04	189.42	188.20			
30	188.68		189.76	31.20	190.91	179.76	185.91	187.67	182.73			
31	169.28		190.80		201.00		189.29	177.43				
	5770.21	5294.66	5846.52	5530.22	5815.13	5490.81	5540.05	5701.50	5458.93			

Table 30-Salaulim Reservoir 160 MLD (Water Treatment Plant) Withdrawal data in the Year 2019

22.0 Deliverable Drawings:-

All the drawings of the dam are enclosed as

Annexure-IV:-