TECHNICAL REPORT NO. **November 2020**

Bathymetry Survey of Khuga Reservoir in Manipur State under National Hydrology Project (NHP)

1.0 INTRODUCTION

Khuga Dam is a multipurpose project which is constructed across the Khuga River near village Mata and is located at about 10 Km from Churachandpur town of Imphal city in Manipur. The purpose of this dam is to cater the needs of drinking water and water supply for irrigation to most part of Churachandpur town and its nearby surroundings. It is a zone earth fill dam in India, constructed by National Projects Construction Corporation Limited (NPCCL) which was started in the year 1983-84 and completed in the year 2010. The dam is 232 m long and 38 m in height.

The Executive Engineer, Water Resources Department, Govt. of Manipur vide letter no. IFCD/NHP/1-1/2015-16/128 dated 26.07.2019 has requested National Project Monitoring Unit (NPMU), New Delhi for conducting bathymetry survey of three reservoirs Singda, Khuga and Khupam situated in Manipur state under National Hydrology Project (NHP). Subsequently after accepting the proposal by CWPRS, the CWPRS team carried out hydrographic survey of the three reservoirs during 16-27 January 2020.

1.1 Khuga Dam Project – Salient features

The construction of the dam started in the year 1983-84 and completed in the year 2010 with a project cost of Rs.381.28 crores. The main objective of the dam is to provide drinking water to Churachandpur town in Imphal, proper irrigation facility to its nearby area. The view of Khuga dam is shown in Photo. 1. The spillway of Khuga dam is shown in Photo. 2. The Google image of Khuga dam with data logging point is shown in Photo. 3. The salient features of Khuga dam project are as given in Annexure-1.

Photo 1: **Khuga Dam upstream view**

Photo 2: Spillway of Khuga dam

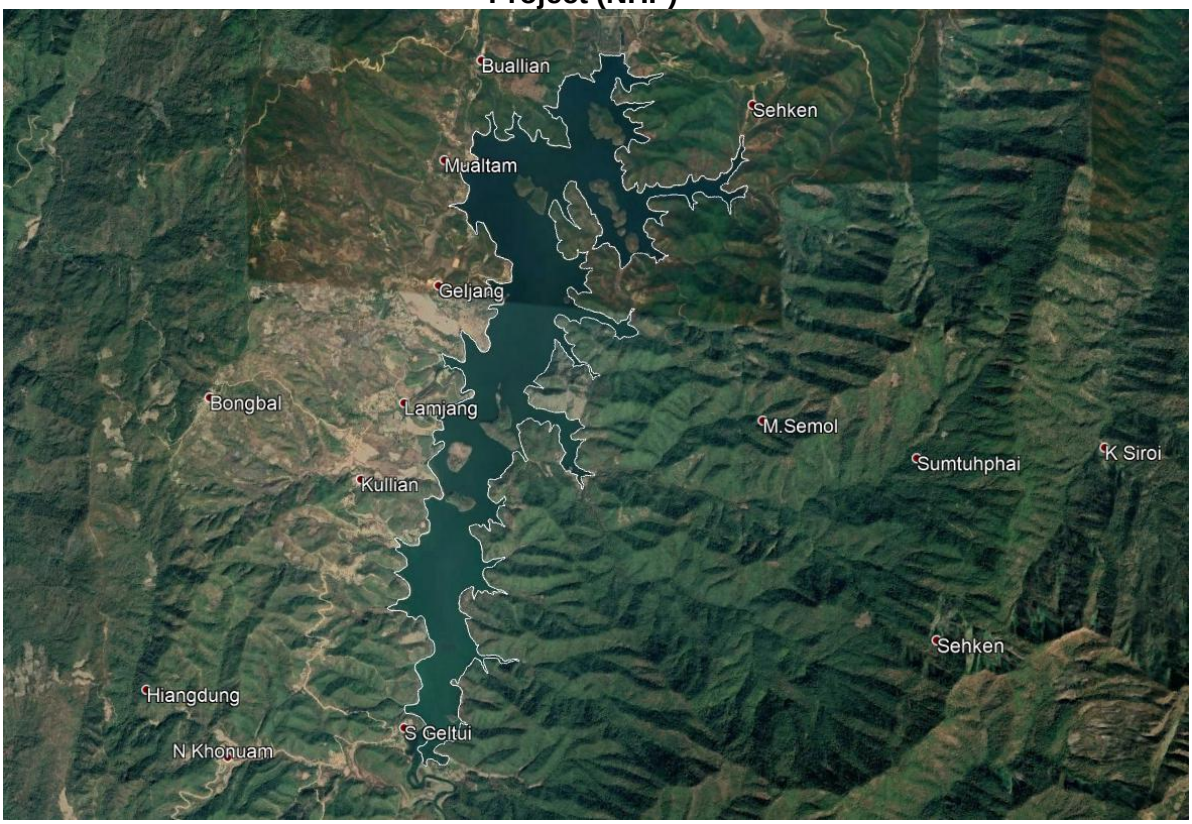

Photo 3: Google image showing the Khuga reservoir

Shri Lian Samatee, Executive Engineer, Shri S Thuamlallian Executive Engineer, Khuga spillway & Intake division (KS&ID), WRD,Govt. of Manipur, and other dam officials took part in the discussions and shared the hydrological data pertaining to the reservoir with CWPRS team during the survey period at site. The following officials of CWPRS were involved for carrying out bathymetric survey work from 24th to 27th January, 2020, Shri M. S. Bist, Scientist-C, Shri Ajay Sonavane, A.R.O, Shri Ajit Singh, R.A. and Shri K. Subbarao Murthy, J.E. The CWPRS team with Khuga dam officials at Khuga dam site is shown in photo 5.

Photo 5: CWPRS team with Khuga dam officials at dam site

1.2 SCOPE OF STUDIES

The scope of the studies was to carry out sedimentation survey of Khuga reservoir for assessment of silt and to find out the present storage capacity of reservoir. For bathymetry survey a motorized fiber boat arranged by project authority was used. The eco-sounder sensor with special fixture was fitted on one side of the boat and the GPS antenna was mounted on the same end to collect the DGPS locations precisely. The echo sounder used during survey was single beam dual-frequency eco-sounder (210Khz, 33 Khz) Knudsen make and the GPS was Trimble make.

1.3 OBJECTIVE OF SURVEY

The purpose of the bathymetric survey was to find the present storage capacity and silt deposited in the reservoir. This will help the dam authority for utmost utilization and proper planning of distribution of water supply for irrigation and drinking purpose. It also includes finding out the possible methods to enhance the dam water storage capacity by means of removal of silt from the reservoir.

2.0 RESERVOIR SEDIMENTATION PROCESS

Sedimentation surveys are important in the reservoir for optimum reservoir operation based on realistic assessment of available storage. Reduction in the storage capacity beyond a limit prevents the reservoir from fulfillment of different purposes. Figure 6

shows the process of sedimentation in a reservoir. Periodical capacity surveys of reservoir help in assessing the rate of sedimentation and reduction in storage capacity. This helps for efficient management of reservoir and also helps in taking decision about treatment of catchment area, if the rate of siltation is excessive.

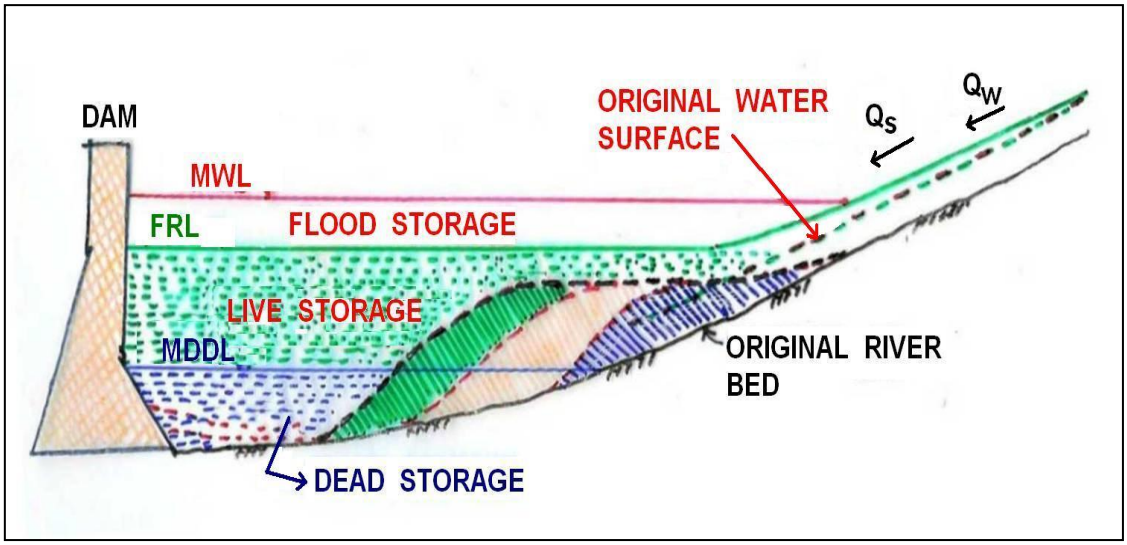

Fig.6: Schematic showing sedimentation of a Reservoir

Among many methods, boat mounted DGPS based bathymetry survey is the most accurate method. This report is based on the Integrated bathymetry survey system used in data collection along with processing of data. This reservoir was designed with a gross storage capacity of **87.08** MCM at FRL 851 m.

3.0 METHODS OF ESTIMATING THE RESERVOIR CAPACITY

The various methods for calculating the reservoir capacity are mentioned below.

1) Conventional Bathymetry Method
2) Satellite Remote Sensing (SRS) Technique
3) Modern Bathymetric Technique using eco-sounder and DGPS

Nowadays, the widely accepted IBS method for obtaining depth data by using a Single-Beam Echo-sounder (SBES)/Multi beam echo-sounder with position provided by electronic ranging equipment. Subsequently, positioning measurement has been made more accurately and easier with the advent of DGPS and RTK.

In the subsequent chapter, IBS bathymetry system is described in detail which was used during this survey.

3.1 MODERN BATHYMETRIC TECHNIQUE USING ECO-SOUNDER AND DGPS

The system consists of the hi-tech equipment components are :

i) Positioning system which includes Transponder or DGPS unit

ii) Depth Measuring Unit consisting of single beam echo-sounder and Transducer

iii) Data Processing software in a computer system

A boat equipped with the bathymetric equipment having a GPS system mounted on board with its reference station positioned on a known geographical benchmark for establishing accurate position along with single beam dual frequency echo-sounder mounted on boat for depth and a lap-top computer for data collection was used in bathymetric survey. The survey software enables fixing of grid lines and interfacing of bathymetry and DGPS, taking x, y, and z values at required interval/grid. Boat navigation is also controlled by the software, so that boat tracks the grid line accurately. The survey can also be carried out at random mode. The data collected is then processed and analyzed using specially developed software to obtain the results in various forms e.g. point plots, contour and 3D maps of reservoir bed, area capacity elevation tables and cross-sections of reservoir. Fig.7 shows the DGPS technique in survey activity.

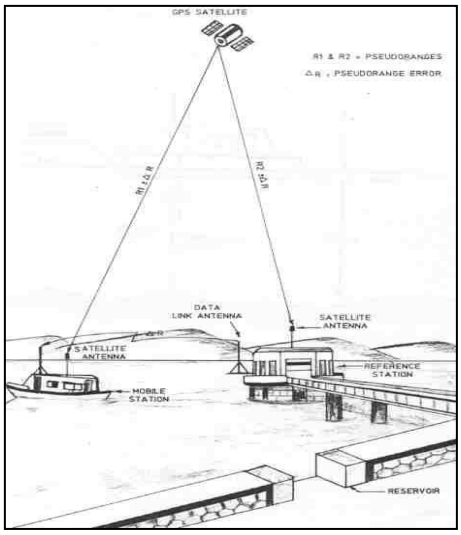

Fig.7: DGPS technique in survey activity

DGPS hydrographic surveying allows faster data acquisition with better accuracy than any previous hydrographic survey technique. The line of sight from the base station to the boat is not necessary. The base station is set up only once per survey, instead of the usual once per cross section. A DGPS survey can be completed between control points (even on opposite side of a mountain) without having to traverse or even to see the other point. Other advantages are the ability to achieve centimeter accuracy and the ability to efficiently collect large amount of data. The photo of eco-sounder with data logging system is shown in Fig 8.

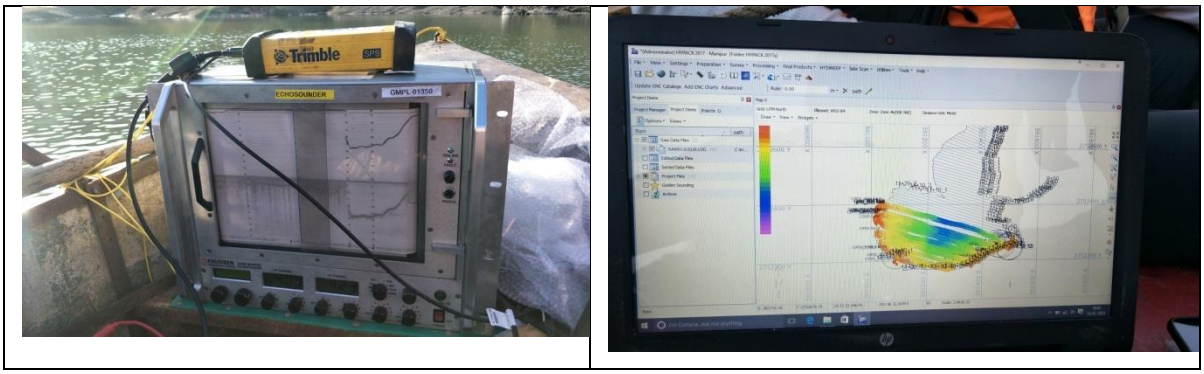

Fig.8 :Echo-sounder with Laptop for logging real-time data acquisition-IBS Equipment

4.0 INSTRUMENTATION SYSTEM DEPLOYED DURING SURVEY

The survey was done at EL 844.0 m and the Integrated Bathymetric system (IBS) used during this survey consists of modern sophisticated electronic equipment consisting of GPS, Echo sounder, Discus antenna, sensor along with the fixture to hold the sensor. The echo sounder used during survey was single beam dual-frequency eco-sounder (210 KHz, 33 KHz) Knudsen make and the GPS was Trimble make. Data collection, processing and calculations were done by means of Hypack software. With the use of this advanced Integrated Bathymetry system the results are more accurate.

The components of IBS used are given below.

4.1 Differential Global Positioning System (DGPS)

The Positioning system which includes Transponder or DGPS unit is one such highly reliable, accurate, state of art device to get position by observing satellite. It can also track

up to 12 satellites to achieve maximum positional accuracy. The GPS receiver receives error correction from reference station and combines them with the received satellite signals to compute much more accurate self-position. The Trimble make GPS display interfacing unit, Echo sounder sensor and antenna used during survey is shown in Fig 9.

Fig.9: DGPS with antenna

The mobile antenna logs the instantaneous position data from the available GPS satellites and corrects the satellite introduced errors with the help of beacon correction. The Trimble DGPS with beacon correction (Beacon station name: Sagar Island) was used during this survey through which GPS and Glonoss data were received. By carrying out survey in this way, the position was logged with sub meter accuracy during the total survey.

The survey area was near to coastal zone with the DGPS receiving beacon correction from the Beacon station Sagar Island. The integrated bathymetric system with GPS was compact and could be accommodated in smaller boats..

The Integrated Bathymetric Survey (IBS Equipment) consisting of echo-sounder and DGPS with Laptop interfaced for online data collection mounted on a survey boat is shown in Fig 10.

Fig.10: Survey Boat with GPS Antenna along with Mechanical Fixture for Eco-sounder

The dam water level scale marked on the dam wall is shown in Fig 11. It is used for recording dam water level day to day purpose.

4.2 ECHO-SOUNDER

The Knudsen make single beam dual frequency echo-sounder as shown in Fig. 11 is used for measurement of depth having following specification. Range : 0.2 to 200m and accuracy of 0.01m +/- 0.1% of depth @ 210 KHz and 0.10m +/- 0.1% of depth @ 33 KHz. This dual frequency echo-sounder is specified to distinguish between top depth and the consolidated bottom. The high frequency (210 KHz) is used to detect the top of the mud/sediment. Under favorable conditions the low frequency signal (33 KHz) can penetrate into the bottom and reveal information about the bottom structure. This system has control to set the energy levels of the beams being transmitted under water. The velocity of sound is an important parameter, which is set at 1500 m/s based on the sound velocity calibrator readings. The same was cross checked with Knudsen echo sensor.

Fig.11: Echo sounder read out unit with sensor

The data collection was done with eco-sounder kept in dual frequency mode throughout the survey on the predefined survey lines.

4.3 LAPTOP WITH NAVIGATION SOFTWARE

The real time position and depth data acquired were stored in the laptop through Hypack navigation software as shown in Fig.12 below.

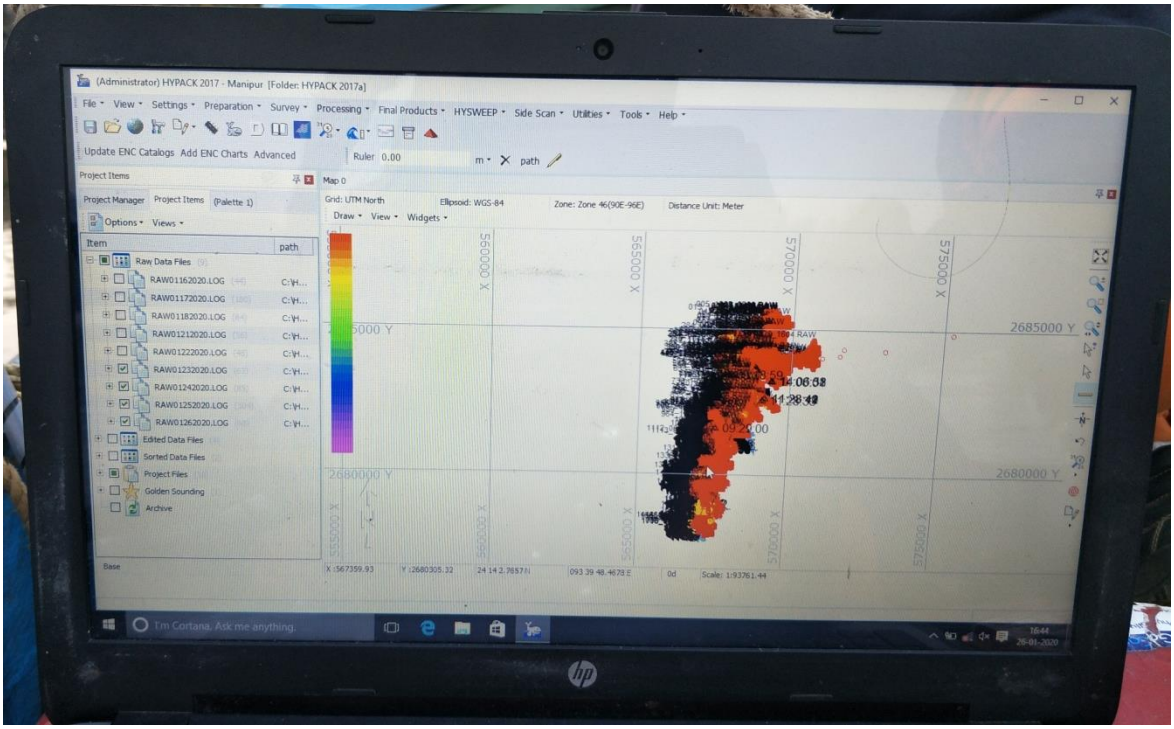

Fig.12: Data logging through Hypack navigation software in laptop

4.4 DATA COLLECTION SYSTEM

The Data collection system consists of a Laptop loaded with Hypack survey software. The Hypack survey module collects the depth data from the echo- sounder which is linked with the position data. The data was collected 10 meters grid interval near the spillway and at 50 meters rest of the reservoir area and this was logged as ".RAW"

format data for further analysis. This software was used to plan and collect the data for data processing which was runs in the laptop and through USB serial port.

5.0 METHODOLOGY OF SURVEY

The survey was carried out with a boat equipped with the ultrasonic dual frequency echo sounder, Mobile GPS system with Beacon correction data mounted on

board and a lap-top computer. The Hypack survey software is used for fixing of grid lines and interfacing of bathymetry equipment and GPS by taking x, y, and z (depth 1 and2) values at 50 m grid interval/grid. Boat navigation is also controlled by the software so that boat tracks the grid line accurately.

The survey can also be carried out at random mode without survey lines. The data collected is then processed and analyzed using specially developed software (Hypack) to obtain the results in various forms e.g. point plots, contour and 3D maps of reservoir bed,

area capacity elevation tables and cross-sections of reservoir. DGPS hydrographic surveying allows faster data acquisition with better accuracy than any previous hydrographic survey technique. The line of sight from the base station to the boat is not necessary. A DGPS survey can be completed between control points (even on opposite side of a mountain) without having to traverse or even to see the other point. Other advantages are the ability to achieve sub meter accuracy and the ability to efficiently collect large amount of data. However, the present survey area is near to coastal zone which receives the beacon station correction data from Sagar Island. The data collected system with GPS is compact and can be accommodated in smaller boats.

6.0 DATA ANALYSIS AND INTERPOLATION

The data collected at dam site was analyzed at CWPRS using various processing software such as Hypack, Surfer, Eiva. The uneven data was brought to a regular grid form by applying krigging method for elimination of noisy spikes and for getting the useful data samples (depth values). Special filters were used to clear the spikes in the bathy data. Mostly the noises attribute to the boat movement under water vegetation, engine and the surface wave noise. The processed data was used for further analysis in SURFER software. The depth data was processed initially for preparing grid files. These grid files were used to prepare contour plots, surface plots and for the estimation of volume as well as surface area by standard formulae such as Trapezoidal rule, 1/3 Simpson's Rule and Simpson's 3/8 Rule together. The survey was carried out at elevation of 844.0 m. The results were based on the interpolation of the depth data acquired by the

echo-sounder in dual frequency mode. This data is interpolated by krigging method for the zone lying in between two survey lines. This generates the grid data set, which was used for the data analysis. For estimation of volume, the methods used were Trapezoidal Rule, Simpson's Rule and Simpson's 3/8 Rule jointly. Volume found using bathymetry survey at EL 844.0 channel 1 depth (210 khz) was 55.361MCM and corresponding area was **0.3957** sq .km.

The Table 1 shows the volume and area corresponding at different elevation.

Table 1

Sr. No.	Elevation (in m)	Volume (In M.cum)	Area (In Sq Km)
1	820.0	0.000009	0.000062
2	821.0	0.00069	0.002416
3	822.0	0.00820	0.0146
4	823.0	0.0352	0.04261
5	824.0	0.1025	0.0986
6	825.0	0.2447	0.1933
7	826.0	0.520	0.3664
8	827.0	1.013	0.630
9	828.0	1.773	0.884
10	829.0	2.751	1.0748
11	830.0	3.955	1.3657
12	831.0	5.531	1.7815
13	832.0	7.508	2.1625
14	833.0	9.845	2.5014
15	834.0	12.492	2.814
16	835.0	15.480	3.1557
17	836.0	18.817	3.519
18	837.0	22.525	3.920
19	838.0	26.654	4.321
20	839.0	31.096	4.541
21	840.0	35.751	4.767
22	841.0	40.60	4.901
23	842.0	45.516	4.9225
24	843.0	50.44	4.9225
25	**844.0**	**55.361**	**4.9225**

After necessary interpolation of the data different graphs have been plotted. Volume - Elevation and Area -Elevation curve are shown in Figs. 13 and 14.

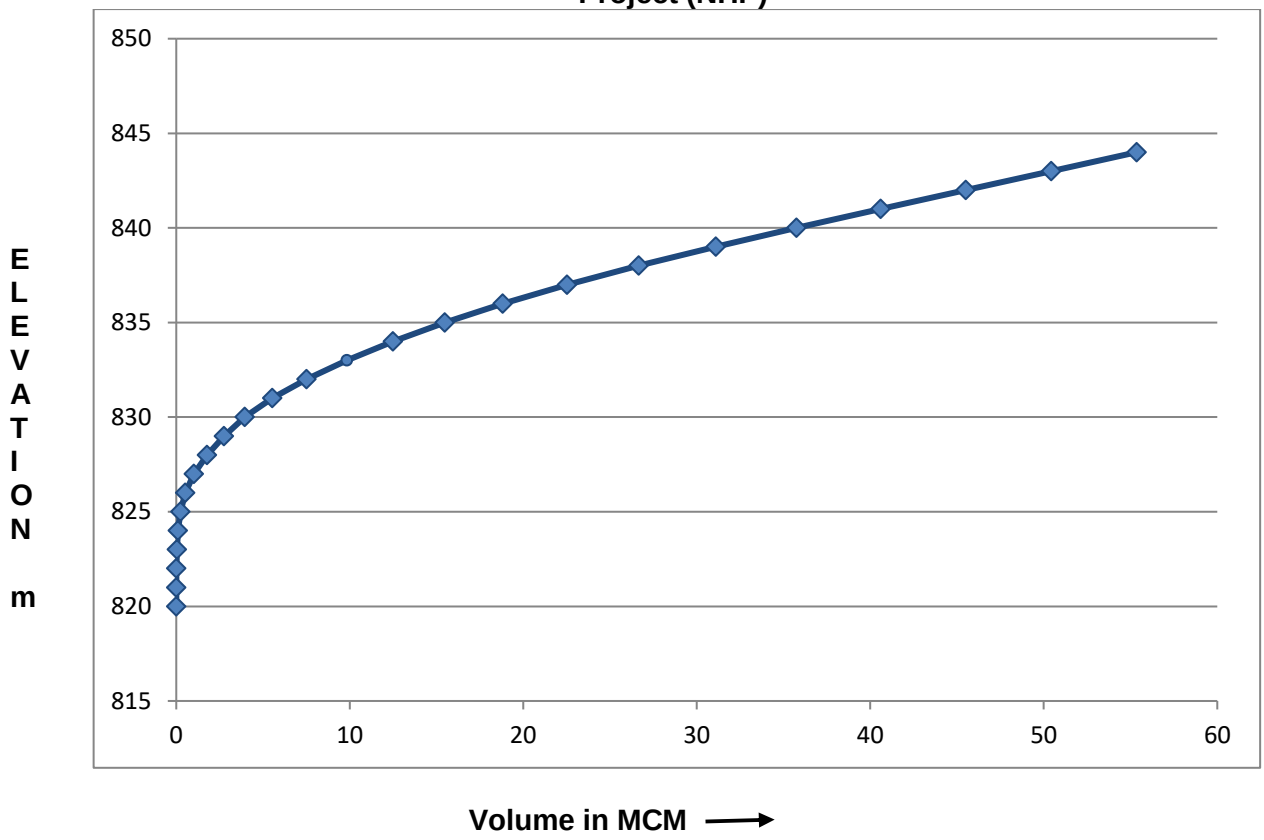

Fig. 13: Elevation- Capacity curve of Khuga reservoir

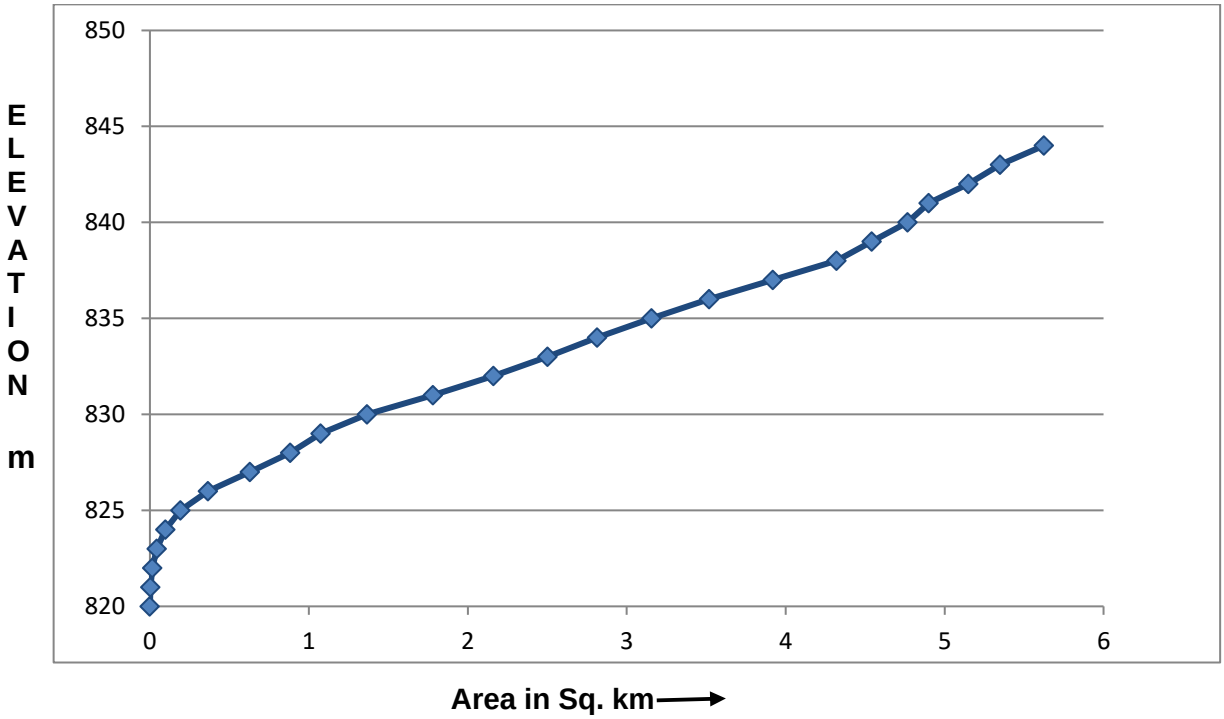

Fig. 14: Elevation- Area curve of Khuga reservoir

The Area-Capacity curve of Khuga reservoir is shown in Fig. 15.

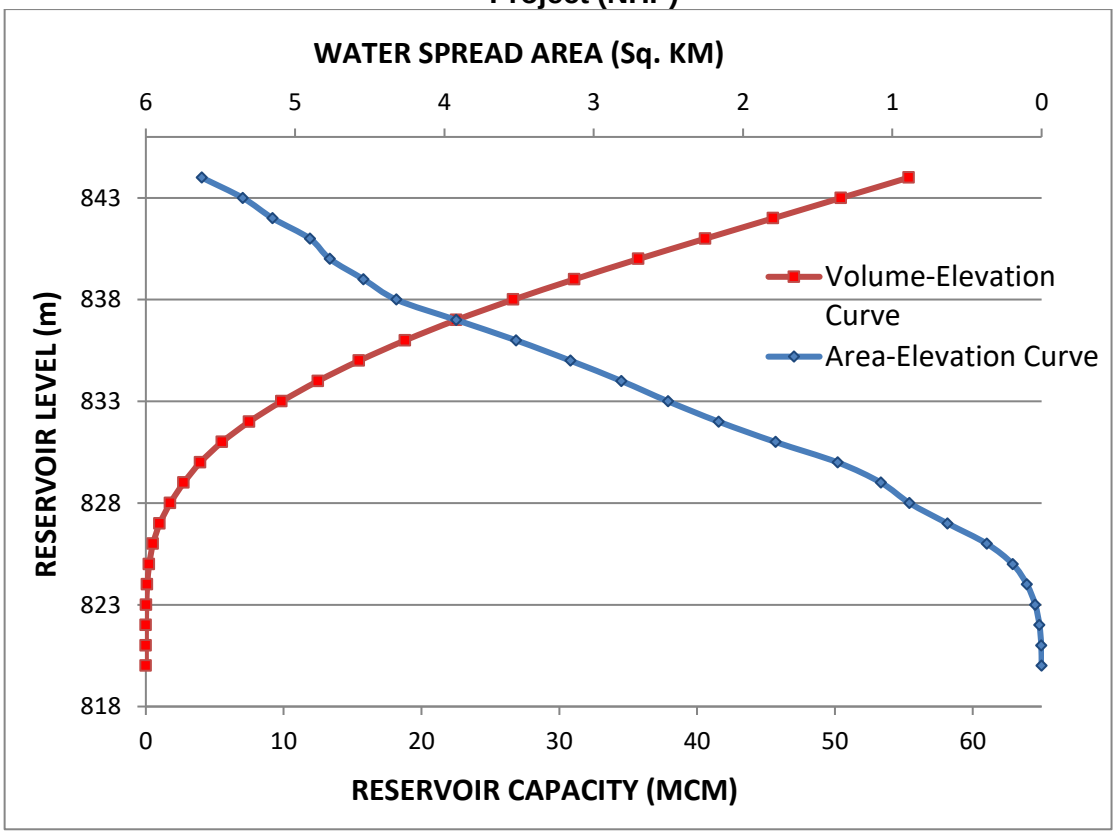

Fig. 15: Area-Capacity curve of Khuga reservoir

The surface map is shown in **Fig. 16**. The contour plot is enclosed in Annexure 2 and depth profile plot is enclosed in Annexure 3.

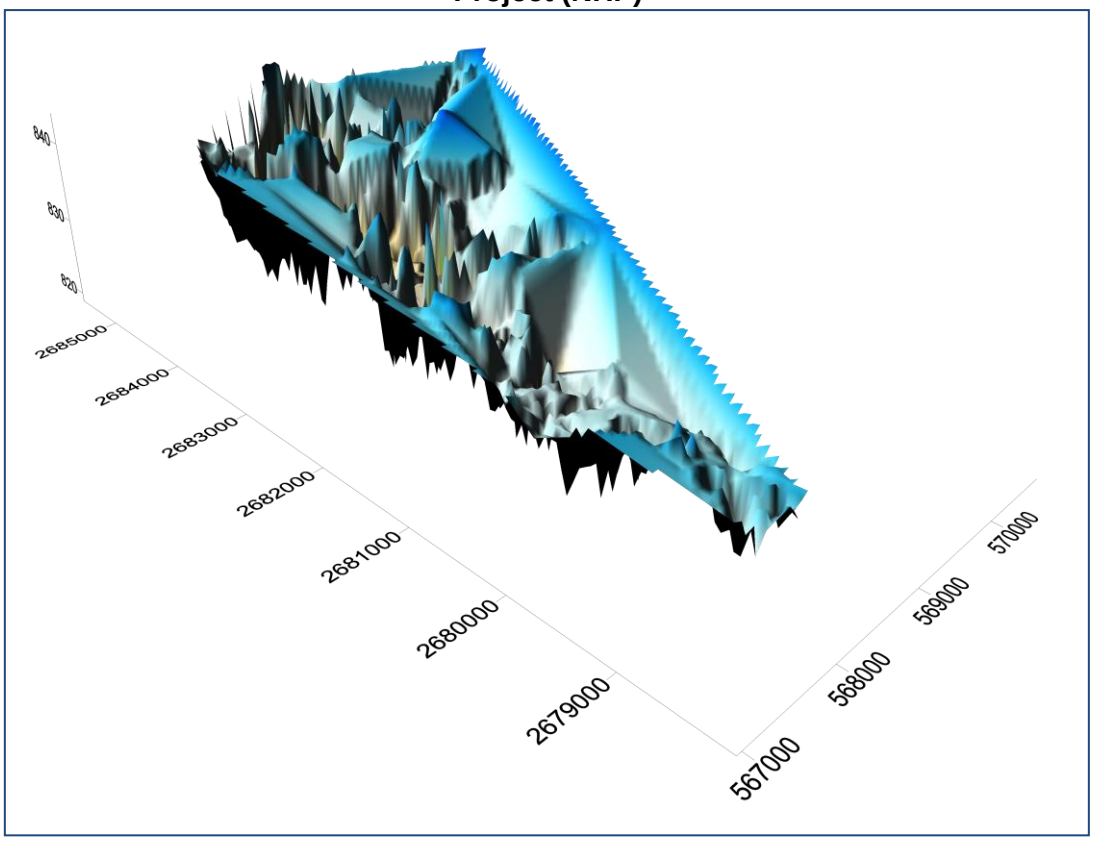

Fig. 16: Elevation- Surface map

By using IBS system, the reservoir gross storage capacity calculated at EL **844.0** m during survey is **55.361** MCM for a water spread area of **4.9225** Sq. km.

7.0 RESULTS & CONCLUSIONS

The bathymetric survey result is tabulated in **Table 2.**

Table : 2

Sl. No	Elevation (m)	Gross Storage Capacity (M.CM)	Water Spread Area (Sq.km)	Original Gross capacity (M.CM)	Capacity loss (in %)
1	844.0 m (During survey)	55.361	4.9225		

When compared with original gross storage design data which was 9.71 MCM, there is a reduction of 3.33 MCM i.e. 34% in the gross storage capacity of the reservoir at FRL 909.50 m.

When compared with original live storage which was 8.51 MCM, there is a reduction of 2.13 MCM i.e. 25 % in the live storage capacity of the reservoir at FRL 909.50 m. There is an average annual loss in the live storage capacity of 1%.

Hence, the amount of silt deposited is 3.33 MCM as compared with gross storage capacity. During the first survey conducted by CWPRS after the construction of Khuga dam, it was observed that there is a substantial loss in gross storage capacity during a span of 25 years. From the above observations, it is suggested to de-silt the reservoir in order to restore the dam's original storage capacity. This will increase the life span of dam and will cater the need for which it was constructed.

8.0 ACKNOWLEDGEMENT

We acknowledge Shri A.K. Agrawal, Director, CW&PRS, Dr. Prabhat Chandra, Scientist-E and Dr. L. R Ranganath Scientist-D (TC) who have provided necessary support during preparation of this report.

Our sincere thanks due to Shri Rohit Ahanthem, Superintending Engineer, Irrigation Circle-II, WRD, Manipur Shri Irom Royal, Ex. Engineer, Shri Lian Samatee, Executive Engineer, Shri S Thuamlallian Executive Engineer, Khuga spillway & Intake division (KS&ID) and others officials in Irrigation division of Khuga Dam project, who have extended their support in providing all necessary arrangements required for carrying out the hydrographic survey. We are also thankful to M/s Geoservices Maritime Ltd., Navi Mumbai for sparing the latest bathymetric equipment for this survey work.

Annexure: 1

I Location of Dam

Dam site	:	Near village Mata across Khuga river about 10 km from Churachandpur town, Imphal
State	:	Manipur
River	:	Khuga
Latitude	:	24^0 00' North
Longitude	:	93^0 50' East

II HYDROLOGY

Catchment area upto dam site	:	3215 sq.km
Normal annual rainfall	:	1320 mm
Design flood discharge	:	1844 m^3/ sec (65,000 cusecs)

III Reservoir

Gross storage capacity	:	87.08 MCM
Live Storage Capacity	:	60.40 MCM
Dead storage capacity	:	26.68 MCM
F.R.L.	:	851 m
M.W.L.	:	852.81 m

IV Main Dam

Type	:	Zoned earth fill dam
Total length of earth dam	:	232 m
Max. height of dam	:	38 m
Top level of dam	:	EL 855 m

V Spillway

Type	:	radial gate side chute spillway
Location	:	on right flank
Capacity	:	1844 m^3

VI Intake

Intake level	:	EL 834 m
Discharge at Head	:	6.84 m^3/sec
Length of main canal	:	84 Km

VII Irrigation Distribution system

Gross command area	:	10545 Hectares
Cultivable command area	:	9575 Hectares
Annual irrigation	:	15000 Hectares